Northfield Water
Supply Study
Environmental Impact Report

Phase I Basic Services
Technical Memoranda Appendix

Submitted to
Metropolitan District Commission

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INTRODUCTION

The findings and recommendations of the literature search performed by the consultants are presented as technical memoranda covering topics outlined in the Phase I Basic Services Scope of Work for the Northfield EIR as follows:

A. Water Use and Demand Estimates

B. Safe Yield and Streamflow

C. Demand Management (Conservation)

D. Leakage and Unmetered Water

E. Conceptual Engineering Studies of Alternatives

F. Power Analysis

G. Water Quality, Ecology - Rivers, Estuaries, Tunnel Rights-Of-Way

H. Water Quality - Reservoirs, Surface and Groundwater Supplies

I. Ecology - Reservoirs, Surface and Groundwater Supplies

J. Socioeconomic Impacts

K. Land Use

L. Significant Cultural Resources

The literature search was intended only to establish whether existing information was adequate to address the major issues raised by each alternative and to identify gaps in this baseline information and recommend any work needed to fill the gaps.

In outlining the recommended scope of the EIR, proposed methods of analysis are described. However, no impact analysis will be performed until the EIR itself begins.

These findings and recommendations are summarized in the Phase I Basic Services Report entitled Findings of Literature Review and Recommendations for Further Study.

Draft versions of the technical memos were reviewed by MDC, NCAC, and the public prior to publication through a review workshop and public information meetings held in June 1980. These are reported in Appendix M. Public Participation.

Answers to questions generated during this review process are included along with the text and bibliography of each technical memorandum.

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TECHNICAL MEMORANDUM:
WATER USE/DEMAND

Phase I Basic Services

submitted to

METROPOLITAN DISTRICT COMMISSION

by

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ATER USE/DEMAND

The analysis of current water use and projections of future demand looks at water consumption among users currently and into the future in several major categories of use: domestic, industrial, commercial, institutional, agricultural, public and unaccounted for water. The components that make up this task can be divided into five tasks which were addressed in the literature search and review. These are: Population projections and water demand forecasts; domestic water usage profiles and use factors; industrial water consumption and demand; other non-domestic water use; and conservation measures which could influence future use. All but the last category are addressed in this report. A separate memo is included in the Appendix which discusses the conservation alternative.

The following sections discuss each of these study elements and present a summary of the findings of the literature review with a proposed approach to the work upcoming.

OPULATION PROJECTIONS/ EMAND FORECASTS

Introduction

Existing population projections made by federal, state, and local agencies were examined in order to determine their currency, validity and overall applicability to the study. Because population forecasts are no more than estimates that lose accuracy the further into the future they are made, it is anticipated that available projections can be used in this study rather than developing new projection figures. When they become available, 1980 census data will be used to update the existing projections.

Forecasts of water use will be made in conjunction with the population projections. Because of the complexity of factors which influence water use a methodology has been developed which will look at consumption and use by category to arrive at individual usage factors which can be projected to 2020.

Questions That Need to be Answered

Population estimates, one component of forecasting water use, have typically been used in conjunction with historical data on water consumption utilizing a uniform per capita consumption rate to develop forecasts of water use in the future. These methods were usually applied across all categories of water users with little or no adjustment for different characteristics of present use or future trends.

Such methodologies had the advantage of being analytically straightforward and simple to calculate, allowed uniformity throughout the analysis and across geographic boundaries, and were readily calculated from data that was available. There are, however, drawbacks to this forecasting technique. It has been suggested that such a forecasting method does not reflect the inherent differences among categories of water consumption. For example, water use differs for

those living in single-family residences and apartments, between industrial process water use and water used for cooling purposes, and between commercial uses and institutional ones.

An alternative method of projecting water use which attempts to incorporate the differences between users involves disaggregation of consumption into categories reflecting individual usage factors. Table 1 illustrates some of the diverse variables that describe water consumption in this way.

Another question relates to the existing statewide population projections that are available. These forecasts are based on 1970 federal census data and were developed by Massachusetts during the early years following the census. The projections are dated in terms of the assumptions that were made in the early 1970's and the lack of current information reflecting regional-local growth trends, economic conditions, household composition, or other comparable factors. Recent events and their influence on trends will be an important element of the updating of existing projections using 1980 census data and working with the RPA's and local planners in the study area.

Another question that is basic to the analysis involves definition of the study area(s). This issue does not pertain to the assumptions on population projections directly since population figures can be developed uniformly at the town and city level for all municipalities across the state. However, in order to identify key issues and trends that may influence growth, assess current consumption, and develop user profiles and use factors by category, it will be necessary to define what study area is considered in order to focus specific analysis. Moreover, on the question of possible future MDC user communities, there are potentially statewide bounds that must be more carefully defined. Because of variations in the elements of the analysis it may be necessary to develop more than one study area to correspond to the range of possible supply measures to be considered.

Data Review and Evaluation

The review of the available literature and data sources involved examination of several different sources of population projections and use forecasts. At the federal level, the Department of Commerce makes projections to the year 2000 based on the census and long-range growth forecasts for the U.S. A national population total is developed and disaggregated at the regional level. Under this method, if growth is projected in one region, for example the Southwest, then it must come at the expense of another, such as the Northeast, assuming no major immigration from outside the U.S.. In this way estimates of the nation's total population are controlled and distributed according to regional growth trends.

A statewide figure for Massachusetts was developed from these regional totals and further disaggregated to the sub-state regional level by the Massachusetts Office of State Planning (OSP). OSP developed these figures in the period 1974-1975 and has since disbanded. During this time, working closely with the state Regional Planning Agencies (RPA's), who in turn worked with the local communities, a set of revised population projections for each municipality in the Commonwealth was developed to the year 2000. These figures were current, for the most part, in 1975 and based on planning expectations in each region at that time. They were subsequently used by the RPA's for their respective 208 Water Quality studies which, in some cases, provide more recent population projections to the year 2000 although the basis for these figures remains the 1970 census.

In addition to this source of statewide projection data, there were separate projections made by the Massachusetts Department of Health to the year 1985. These projections were based on somewhat different methodology and assumptions than those made by OSP, and they correspond to different areas.

Another source of population projections are individual engineering studies done for cities and towns. These reports were done by different consultants at different times under separate engineering studies. As a result, no consistent set of population data are available from these sources. In some cases these studies also make estimates of future demand; these will be considered in the first cut estimate of demand described below. A listing of the engineering studies reviewed is included in the Bibliography to this report.

Still other sources of population projections that were examined involved consultants developing new projections in their ongoing modelling efforts. Several academic and private consultants have developed models which make economic and population projections for the nation and the state. These projections have the advantage of being based upon the most current assumptions and trends. However, the models utilized in these efforts are specifically designed to make accurate short-term forecasts and they become constrained if used for projections beyond 1985 or 1990.

TABLE 1

POTENTIAL COMPONENTS OF MUNICIPAL CONSUMPTION

- Residential: Per Capita/Household Usage
  - Single Family
    - Indoor Use
    - Outdoor Use
  - Multi Family
- Commercial: Employment/Output/Sales
  - Retail
  - Office
  - Restaurants, Supermarkets, etc.
- Industrial: By SIC/Employment/Output
  - Process Use
  - Cooling Use
  - Sanitation
- Institutional
  - Resident Population/Size
  - Employment
- Other
  - Public Use
    - Unmetered
  - Leakage/Meter Slip

Source: WFEM, 1980

A final source of data is the 1980 census. When the first preliminary counts become available they will be a significant source of the most current population information, both to serve as a validation of existing projections as well as to begin to develop a basis for assumptions to be made for the demand forecasts. Final census counts are published much later and will be considered to determine whether any sufficient charge has been shown.

Methods for Filling Identified Gaps and Developing Population Projections

In order to deal with the issues uncovered in this phase of the study, we have incorporated a two-fold approach for the analysis. First, we will analyze existing population projections and estimates of water demand which use a uniform per capita consumption rate. These projections provide historical consumption data to 1970 and make projections of future water use to 1990 for all communities in the state. The source for this data will be the Massachusetts Water Supply Policy Statement prepared for the Executive Office of Environmental Affairs in 1978 and a Metropolitan Water Transmission and Distribution System report done for the MDC in 1975.

Actual water consumption figures recorded between 1970 and 1979 will be compared with the reported projections in these studies and a level of magnitude difference will be drawn. A preliminary sample of this method has shown generally higher reported projections than are reflected by the actual usage figures compared. We would amplify this sample in the upcoming work in order to draw a range of recent actual consumption trends across all of the study area communities. These will provide us with a revised per capita usage factor (still utilizing the traditional uniform measures of use) which will be applied to the existing population projections (based on 1970 census) to develop a preliminary water use estimate for the study area cities and towns.

A second parallel approach involves a more detailed breakdown of current water use. This method is intended to profile and describe the components of water consumption by categories to be identified in the analysis, and then to develop individual usage factors for each category of use. These profiles will be developed from detailed interviews and surveys of a sample of communities that now use or could join the MDC system. In this way, it is anticipated that a more accurate basis for future projections will be available using factors that reflect and differentiate water usage among the individual usage categories.

Table 2 portrays a matrix of the water use categories to be profiled and analyzed in the following stage of the study. Depending upon the amount of information available on each category of usage, and the degree to which the data can be

uniformly disaggregated, we will develop usage factors by user category to project future use.*

Under this matrix, which portrays the range of usage factors to be analyzed, the types of water use are broken down into four major consumption categories: domestic, industrial, other (non-domestic, non-industrial), and unaccounted for water. Under each of these the possible variables which relate to and reflect usage are listed.

DOMESTIC CONSUMPTION

Introduction

Domestic consumption is that component of water use attributable to household activities. It is made up of indoor uses such as drinking water, food preparation and cooking, laundry and dishwashing, household cleaning, bathing and toilet flushing; and outdoor uses of lawn and garden watering, car washing and swimming pool filling.

Domestic consumption is a significant, usually substantial, proportion of total water use. A report by the University of Massachusetts Water Resources Research Center (1972) estimated that domestic consumption in the MDC district in 1972 accounted for almost 1/3 of all water used in the district. Another study by the U.S. Army Corps of Engineers (1974) found that in the portion of Eastern Massachusetts not served by the M.D.C. and not in the Merrimack Valley, water consumption for domestic purposes was over 61 percent of total water consumption in 1970. While such figures vary within the respective service areas (such as more industrial/commercial use in the M.D.C. district), the important point is that in almost all studies of water use publicly supplied, the domestic use constitutes a major proportion of the total.

The wide variation in the two studies cited above does suggest, moreover, that domestic consumption in Eastern Massachusetts and the rest of the state needs to be looked at carefully both with respect to its own components and its relationship to other consumptive water use sectors, including unaccounted-for water. It is suspected from preliminary reviews of the data that in the M.D.C.

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* A preliminary check of this method was made in an interview with Mr. Bruce Nagler, Division Superintendent for Water, Needham Department of Public Works. In reviewing the level of detail available from their records, plus the information and breakdowns that could be developed by his office, Mr. Nagler indicated that it would be possible to develop consumption by the categories listed with estimates of usage necessary in some cases where no hard data was available. It is assumed at this stage of the work that comparable data will be obtainable from other towns as well.

TABLE 2

WATER CONSUMPTION AND USE CHARACTERISTICS

	PRESENT USERS OF MDC SYSTEM	POTENTIAL FUTURE MDC USERS	POTENTIAL IMPACTED COMMUNITIES	OTHER POSSIBLE USERS
1. DOMESTIC CONSUMPTION				
Usage Generators				
• Population/Households				
• Single Family Units				
• Multi Family Units				
Use Factors				
• Per Capita				
• Household				
Use				
• Indoor				
• Outdoor				
• Total Use				
2. OTHER CONSUMPTION				
Public				
• No. of Employees				
• Usage Factor				
• Total Use				
Institutional				
• No, of Employees				
• No. of Residents				
• Use Factor				
• Total Use				

TABLE 2 (cont'd)

	PRESENT USERS OF MDC SYSTEM	POTENTIAL FUTURE MDC USERS	POTENTIAL IMPACTED COMMUNITIES	OTHER POSSIBLE USERS
Commercial				
• Number of Employees				
• Output/Sales				
• Usage Factor				
• Total Use				
Irrigation/Agriculture				
Other Uses				
3. INDUSTRIAL CONSUMPTION				
• Process Use				
• Power				
• Cooling Use				
• Other Use				
4. UNACCOUNTED FOR WATER				
• Leakage				
• Meter Slippage				
• Unmetered Use				
• Hydrant Use				

Source: WFEM, 1980

district some unaccounted-for water is actually unmetered residential usage or residential usage not fully accounted for because of underregistration of water meters. And it is further suspected that domestic usage in multi-family structures has been, in many instances, reported as commercial usage in the basic data relied upon for the 1972 M.D.C. Water Usage Study.

More recent data and better breakdowns and accounting of water use needs to be analyzed under Additional Services of Phase 1 in order to better understand the components of domestic and other categories of non-industrial water usage.

The need for a better understanding of the components of domestic consumption is further heightened because of the fact that municipal water systems, both historically and today, were established to provide water for use in fire protection. Moreover, it has been suggested by studies in California (Teknekron, 1978) and elsewhere that comprehensive water conservaton programs are easier to design, administer and enforce on the domestic side, than in other water use sectors. The literature is more complete on the domestic side as well so that more information is available in this sector than others, such as industrial.

It is noted, that potable water requires a greater concern for pre-treatment than most other water use, and generally has an extensive distribution and storage system with attendant costs of capital works, pumping, and maintenance. Domestic usage is the largest user of potable water and thus commands our attention from this viewpoint also.

Once used, municipal domestic water also requires substantial community, regional, state and federal efforts in waste treatment, water quality and pollution control activities. For the above reasons, we have organized the analysis to consider the components of municipal domestic water use as a major element of the overall water consumption system and a key factor in projecting future demand. Other factors are also considered in the following sections.

Questions Needing Analysis

The selection of water supply alternatives, particularly demand management/conservation alternatives, requires that there be reasonably reliable data on domestic consumption. There is also the need for understanding the broad components of domestic use that are relevant to this part of the country and to the future make-up of domestic users.

Until recently, only total consumption data was available to include use among all major categories of users. Although components of water use such as domestic, commercial, industrial, etc. have been reported in past

studies, there are questions of reliability of this data due to the spottiness and inconsistent classifications of the information (e.g., is multi-family usage commercial or domestic; or, are users recorded by type or by the size of their service?) Recent reporting requirements and survey efforts by the Division of Water Supply (DEQE), the Water Resources Commission and MDC provide a better data source on the components of demand than has ever been available in the past, although this data remains fairly recent and still has some inconsistencies requiring attention.

There still is the need, as well, for further understanding of why and to what degree domestic consumption varies from region to region and one community to another. One of the potential reasons for variability may be outside water use. This question has not been adequately addressed in previous studies and some original data gathering and analysis is necessary to quantify such usage. It was pointed out in the Water Policy Study (WFEM, 1978), for example, that car washing in the yard could consume 60-80 gallons per wash, that lawn watering could consume three times more water than car washing on a per day basis, and that filling a typical sized swimming pool could add as much as 25.5 gallons per capita per day to the family's annual water consumption.

In the western United States (admittedly more arid), it has been pointed out that outdoor usage amounts to 30 to 50 percent of total domestic consumption (WFEM, 1978). No comparable overall assessment figures exist for the eastern United States, but this component of use is undoubdtably significant and will be a consideration of the analysis of domestic consumption. A further discussion of our proposed analysis is provided in the report of our findings.

A third question that needs to be answered is whether domestic household composition and family size will affect future consumption so that it is significantly different from the historical trends. In the 1980's and beyond an accelerated rate of household formation is anticipated; these households are expected to be smaller in their average numbers of persons than in the past. The question to be examined is whether future water use will be changed in any significant direction by these factors.

Studies in California and elsewhere (Teknekron, 1978; Linaweaver, 1967) have suggested that household size or per capita usage is not the key variable for water consumption: that a three person unit would not use one-half more water than a two person unit - that the fraction would be smaller. The implication, if this is true in Massachusetts, is that projection of water use by per-capita figure as has been done in past projections may over-state the use likely to occur in the future. On the other hand, simply assuming that the reduction in the number of persons per family, a recent trend expected to continue, will reduce consumption given the rate of

household formation is also unwarrented. The important question of household versus per capita consumption therefore will need to be analyzed in the Additional Services portion of Phase 1, along with the more detailed breakdown of water use by major non-industrial categories.

Data Review and Evaluation

Interviews were held with the following persons:

- Mr. Thomas Gawrys, M.D.C. Water Division Statistical Office.

- Mr. David Grice, Massachusetts Division of Water Resources.

- Mr. Paul Watson, Massachusetts Department of Environmental Quality Engineering, Division of Water Supply.

Data Sources Reviewed included:

- M.D.C. Water Services and Metering Reports for a sample of communities.

- M.D.C. Water Division Statistics: Monthly and Weekly Consumption Records, Comparison of Average Daily Quantity of Water Supplied, Maximum and Minimum Rates of Flow, Pressure Recorded on Gauges Connected with Distribution Mains, Rates Charged for Metered Water by Cities and Towns in the Metropolitan Water District (or by those supplied but outside the Water District), and Consumption from the Metropolitan System and from local System for Partially Supplied Towns, Monthly.

- Massachusetts Water Resources Commission: Outline of Water Resources Management Plan, Water Supply Element for municipalities and towns without a central supply system and for private water companies.

- Massachusetts Department of Environmental Quality Engineering, Division of Water Supply: Water Supply Statistics by Community, Annual.

- Massachusetts Department of Environmental Quality Engineering, Division of Water Supply: Water Supply Statistics by Community, Annual.

- Lower Pioneer Valley Regional Planning Commission (LPVRPC), Water Supply Facilities, March 1970.

- 208 Water Quality reports for cities and towns within each of the state's Regional Planning Agencies regions.

Useful Information Available but not yet fully analyzed:

- M.D.C. M.D.C. has a wealth of historical data on total consumption by community. Also, recent data on the categories of consumption have been assembled by the statistical office based on community annual reports to the Commission.

- Division of Water Supply, DEQE. The Division has been the main source of data on community water systems outside of the M.D.C. since the early 1920's. Reporting requirements under the Safe Drinking Water Act (instituted since 1978) have expanded the usefulness and reliability of this data.

- Massachusetts Water Resources Commission. The Commission is beginning to require communities to report annually their water plans in a questionnaire format. In 1979 the first full year of the program some 75 to 80 percent of water systems and communities (including those with no central water supply system) have responded. Considerable information on the components of demand (domestic, etc.) is available. The data also offers the opportunity to compare consumption in central systems municipally owned and operated versus private water companies versus no central system at all.

- Regional Planning Agencies. Most of the state's RPA's have conducted some analysis of their regional water supply requirements. For example, the LPVRPC has some information on per capita domestic consumption together with projections of average day demands to the year 2020 from their 208 water quality study. Such Regional Planning Agency reports will assist in developing basic data and determining the range of future water use in various parts of the state.

- Individual Communities. A number of towns and cities have organized their water use data and developed information systems in some cases linked to local water department billings on a computer system. These may be a useful resource in the study; particularly with respect to specialized data collection needs (e.g., indoor and outdoor use), and household compared to per capita consumption.

- New England Region and National. The New England River Basin's Commission has compiled data on total consumption and more detailed data for a selected number of urban water systems. The Southeastern New England (SENE) and U.S. Army Corps of Engineers NEWS (North Eastern Water Supply) studies also

offer useful, though in some instances outdated, information for those study areas. EPA has developed a computerized inventory of all public and private water supplies (supplying greater than 25 persons) and this data provides annual information by state on total consumption, population served, number of services, and number of meters. For broad analysis and comparative data, the U.S. Water Resources Council's Second National Water Assessment has information to help set the stage and provide a reference point for aggregate domestic and other consumptive use categories.

Data Gaps and Deficiencies

The major gaps presently identified encompass household domestic consumption data as well as information on domestic only (excluding nonresidential uses such as commercial) water use. Also, there is relatively little information on the question of indoor versus outdoor consumption by residences.

These broad limitations are not crucial to the requirement of projecting quantities for supply in designing 5ngineering alternatives--an aggregate usage picture would be sufficient for that--but in order to design demand management alternatives and estimate their effectiveness requires that such gaps be narrowed. The need for better information on current consumption and the proposed objective of developing user profiles in order to establish more accurate use factors remains as a way to improve and refine the estimates made. The methods designed to do this are described in the next section.

Methods of Analysis

Issues

The three major issues which emerge from the work in Phase 1 Basic Services as outlined previously above are:

1. Trends in per capita domestic consumption. The question may be raised: How many more water using devices can be invented, installed, and used in today's and tomorrow's households? Is it reasonable to assume continuing increased per capita consumption? The trend in Plumbing and Building Codes and in manufactured devices seems to be toward lesser, rather than greater, water consumption, therefore, what effects can be expected from this element?

2. The Basic Domestic User Is it the individual or the household which is the significant unit of water consumption? As noted earlier, there is at least some evidence that the smaller household may be consuming relatively as much water as the larger. Do apartment

users in this part of the country consume almost as much water as the three to four person single-family home (especially when outdoor use is excluded)? How do the future water consumption implications of this factor effect projections of use and estimated consumption levels?

3. Outside Use In more arid regions this use may be greater, but in this part of the country, it may still be an important component of domestic usage. There are policy implications with respect to lot sizes, landscaped area requirements and/or ratios in local zoning by-laws, and in public open space and parkland planning. Restrictions and water bans usually fall relatively hard on outdoor uses - how effective might such restrictions be in terms of the total consumption picture?

Approach

The objective of this analysis is to provide a basic understanding of present domestic use upon which to frame a reasonable range of estimates for the future. The current information and projections would be incorporated with the results of the consumption analysis into a profile of existing usage for the major categories identified which will be useful for designing the alternatives, for shaping approaches, and for estimating their potential effectiveness.

The analysis will focus on developing a profile of existing domestic use by category, and estimates of future consumption based on the trends that can be factored into the first-cut estimates and subsequent refined consumption analysis.

The development of consumption profiles for each of the usage categories to be analyzed is a major data collection and analysis task, including filling of any data gaps and inconsistencies. To overcome these problems, consumption profiles will be developed using case studies, representative samples, and groupings or classifications of communities based on similarities in their water usage and other characteristics. There is sufficient data for aggregate types of analyses, and for drawing reasonable conclusions about domestic consumption in the future. Where more specific information is needed a survey or sample method of collecting data will be employed based on the survey of local water departments. The sequential order of tasks to accomplish the required results include:

Collection of Data on Issues

Data collected and analyzed including historical per capita domestic consumption, consumption by various sizes of households, and consumption for outdoor use.

As noted earlier, there are gaps in this information and the following methods will be used to fill them:

1. For per capita and historical per capita domestic consumption, only recent data (1978, 1979) is available from M.D.C., DEQE and WRC that is largely consistent and complete, including some breakdowns by category of users, but there remain gaps in this data that require further consideration. Earlier data is available but no useful information to detail usage categories exists. Some information from individual communities' water departments (e.g. Boston) also is available, but again the most current data is the most useful. For an historical perspective on per capita domestic consumption only the data from mostly residential communities can be used, or communities in which non-domestic and per capita consumption can be factored out. Local engineering reports and data from other sources throughout the country can be drawn upon to substantiate local information and findings from case studies.

2. For the components of indoor domestic use, the most feasible alternative is to rely on what other studies have found throughout the nation added to the results of the proposed survey of domestic usage in selected sample MDC user communities. There is a presumption, made in other studies looked at, that there is a relative homogeniety in household indoor usage whether in Boston or Tucson, Arizona with respect to water using appliances and water habits per household. This assumption will be considered and analyzed and to the extent that it is supported, standards from comparative geographic areas will be applied. The comparison of seasonal variation will also be applied.

3. For outdoor consumption it is anticipated that monthly seasonal data in a representative number of communities encompassing a common range of residential densities and housing types will give an indication of outdoor use. The assumption is that the seasonable peak usage in summer months compared to comparable winter consumption is reflective of outdoor use after any other seasonable factors are identified and accounted for. The findings of this analysis will be checked against local and national sources and studies for consistency and reasonableness.

4. For household consumption, multi-family residences and single-family areas with large as well as small lot sizes will be identified (the former will probably be in developed surburban areas and the latter in older urbanized areas). Data on water consumption will be collected from M.D.C. and local sources for these selected case study areas. Data on household sizes will be determined or interpolated from census data, other development standards, and local sources. The findings will be compared to other available national studies.

Analysis of the Issues

Data collected on the above issues will be reviewed to determine if there is significant variation in use per capit and use per household size. Similarly, the data will be examined to determine if there are significant differences i water consumption in high density versus low density residential areas that are reflective of outdoor use.

Develop Domestic Use Factors

Based on the above analysis of consumption, use factors will be developed; these factors will then be applied to the most current population projections in order to project demand to 1990, 2000 and 2020 for the communities in the study areas identified.

Based on an analysis of past and recent per capita consumption trends, a determination will be made with respec to future trends for the 1990, 2000 and 2020 projections. I is expected that a basic trend line in the use factor(s) through 2020 will be established, with the underlying assumptions explicitly stated.

Prepare Domestic Consumption Estimates for 1990, 2000 and 2020

Utilizing 1980 census figures and pertinent socio-economic data (as described in Table 1) developed for the study areas, the domestic consumption use factors will be applied to estimate total domestic consumption in 1990, 2000 and 202 for each community. It may prove necessary, where trends or data limitations require, to make some projections on an aggregate basis, however, this is not anticipated at this time.

Apply Conservation Factors

Based on experiences with conservation programs locally and elsewhere, plus the consumption profiles developed in this analysis, the impact of alternative conservation measures on projected domestic consumption will be made.

The analyses preceeding this task would produce domestic consumption estimates for the future in the absence of any conservation activity. The potential range of effects of conservation activity on the basic trend line will be estimated, according to the parameters discussed in the separate conservation memo.

NON-DOMESTIC, NON-INDUSTRIAL CONSUMPTION

Introduction

This category of consumption includes other types of metered water use not analyzed under the categories of Domestic or Industrial. It includes four major sub-divisions of usage: Commercial, Institutional, Agricultural, and Other "Daytime" uses. These can be further broken down into a variety of activities examples of which are listed in Table 3.

This classification of water use has elments characteristic of both domestic and industrial use. Some non-domestic water users, hotels and motels for example, exhibit similarities to consumption by domestic users. Other users like car washes, laundries, agricultural irrigation, and quarrying operations, use water in their "processes" similar to industry. Still other users such as hospitals, institutions and office buildings may use significant amounts of water, as well, in their own right.

TABLE 3: NON-DOMESTIC, NON-INDUSTRIAL WATER USES

Subdivisions/Activities			
Commercial	Institutional	Other "Daytime Users"	Agricultural
Retail Stores	Schools	Construction	Irrigation
Restaurants	Churches	Mining & Quarrying	Livestock
Office Buildings	Parks, Recreational	Transportation	Nurseries
Hotels/Motels	Public Buildings		Greenhouses
Car Washes	Colleges/Universities		
Service Stations	Correctional Institutions		
Laundries	Military Establishments		
Personal Services	Hospitals		
Professional Services	Golf Courses		
Business Services	Cemeteries		

The 1975 MDC Water Usage Study estimates that in the MDC Water District the non-domestic category of water use accounted for about 16-17 percent of use from within the member communities, and about 2 percent of the total system use of the non-member communities; most of this use being from the commercial and institutional sectors. Agricultural and "other" categories of water use are not significant in terms of usage in the existing MDC system. These uses may, however, be highly important in the communities where they occur and in parts of the state outside of the MDC system. Table 4 shows the breakdown of these components of water use.

Little data has been found to exist for agriculural water usage at the local level since most such use is from private supplies, however, for New England overall in 1975 total withdrawls from surface and ground water for agricultural uses were estimated to be 53 million gallons per day on the average. Projected agricultural water use for irrigation and livestock is expected to be 60 mgd by 1985 and 65 mgd by 2000 (U.S. Water Resources Council, 1978). No similar data has been found with respect to the category of "Other" usage within the general non-domestic category.

The commercial and institutional sub-divisions of this category reflect some interesting tendencies as shown in the Water Usage Study (MDC, 1975). After identifying the 5 largest water users in each community from that study, it was found that 72 of the largest water users were institutions (as defined in Table 3) and 33 were commercial users. A summary of that data is presented in Table 5.

What is of particular interest in this compilation is that there seem to be a relatively small number of institutions accounting for a significant amount of usage in that sector. Conversely, in the commercial sector, the demand, even for the larger users, is only a small part of the total; demand in the commercial sector apparently comes from a large number of relatively small users.*

TABLE 4

COMPONENTS OF NON-DOMESTIC CONSUMPTION
1972 - MDC MEMBERS AND USERS

	MDC Members		MDC Non-Members		TOTAL	
Water Use Categories	MDC	Percent**	MDC	Percent**	MDC	Percent**
Commercial Use	39	10	5	1	44	12
Insitutional	22	6	4	1	26	7
Other "Day" Users	***					
Agricultural	***					
Totals	61	16	9	2	70	19

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* Insignificant

** This may in part be attributed to the fact that in the Water Usage Study, because of identification problems, "commercial" users were defined as those whose water consumption did not exceed 155,000 cubic feet per month (12 million gallons per year). Users over this benchmark were classified as industrial. Some small commercial users, most likely, are classified as residential, further obscuring the actual consumption figures.

*** Percent of total MDC and community supplied water, approximately 376 MCD.

Source: Metropolitan District Commission, Water Usage Study, June 1975

TABLE 5

NON-DOMESTIC CONSUMPTION BY
LARGE WATER USERS - 1972*

WATER USE CATEGORIES	NUMBER OF LARGE NON DOMESTIC USERS: MDC MEMBERS	MDC NON-MEMBERS	AVERAGE DAILY CONSUMPTION (MGD): MDC MEMBERS	MDC NON-MEMBERS
Commercial Users	32	1	1.20	.03
Institutional	59	13	10.00	1.50
Other "Day" Users	N/A	N/A	N/A	N/A
Agriculture	2	1	.05	.00
Totals	93	15	11.25	1.53

N/A = Not Available

* Defined as being among the 5 largest water users in each MDC-served community.

Source: MDC, Water Usage Study, 1975

Questions To Be Addressed

Water use in the non-domestic, non-industrial sector, representing almost 20 percent of the current system's total use, is a significant factor in the present MDC system. For projection purposes and for analysis of the conservation alternative it is, therefore, necessary to review the underlying factors and characteristics associated with this usage.

Unfortunately, the data base for constructing a complete profile of this category of use is largely incomplete. However, based on some general breakdowns of non-domestic use at least one level of detail can be defined and possibly more.

The separation of major from non-major users under this category will be the initial focus of the analysis. This division clearly seems to be most important for the institutional sector, although there are significant large commercial uses, particularly hotels and restaurants, car washes and similar large consumers in individual communities that also might need to be reviewed on a case by case basis.

Data Review and Evaluation

Data sources and contacts made are similar to those described in the Domestic Use Section.

Interviews were held with:

- Mr. Thomas Gawrys, MDC Statistical Office
- Mr. David Grice, Massachusetts Division of Water Resources
- Mr. Paul Watson, Massachusetts Department of Environmental Quality Engineering Division of Water Supply.

Data Sources reviewed include:

- MDC Water Services and Metering Reports for a sample of communities.
- Massachusetts Water Resources Commission, outline of water resources management plans - three forms, one for municipalities with a central water supply system, one for those without a central system, and one for those served by water companies.
- Massachusetts Department of Environmental Quality Engineering, Division of Water Supply, Water Supply Statistics by community, annual.

Information Available

The data sources reviewed above provide some preliminary indications of water consumption in the commercial, institutional, and agricultural categories. The availability of such data is relatively spotty; its reporting depends largely on the quality of local water utilities' records plus the time and manpower to respond to requests for this information. The efforts of MDC and DEQE's Division of Water Supply in the past two to three years to obtain a more uniform and accurate accounting of water use are developing some additional data, but this is not as yet complete nor accurate for these categories. Information on "Daytime" Users is likewise incomplelte and largely unavailable.

Data Gaps

The data and literature search has uncovered no more current or comprehensive review of non-domestic, non-industrial consumption since the 1975 Water Usage Study. Even that study had to deal with gaps and data collection problems, such as the difficulty of identifying commercial users simply from the names listed in water department records, and it is anticipated that these and other problems will persist.

New England-wide projections of commercial, institutional (public) and agricultural water use were made for the years 1975, 1985, and 2000 by the US Water Resource Council (WRC, December 1978), and some aggregate projections for Massachusetts and regional breakdowns could be made by step-down methods. The reliability and reasonablness of such an approach will be examined in greater detail during the next phase of the analysis as part of the overall matrix of consumption categories.

Methods for the Analysis

As with the domestic and industrial sectors there needs to be aggregate projection of consumption in this category as well as an analysis of the reasons underlying usage and an assessment of how these relationships might change in the future.

In order to describe existing and future non-domestic, non-industrial consumption, the usage generators and use factors have to be determined for the components illustrated in Table 6. Total consumption in the commercial, institutional, agricultural and other sectors identified would be obtained from data developed in the survey and analysis of current consumption.

In Table 6, the commercial and institutional sub-divisions are further divided into major and non-major users; there seems no point in such a division for agricultural and other users given the availability and detail of the data. Listed

along the left hand column are the major usage generators and use factors to be determined and analyzed during additional services; they are discussed in turn below.

Usage Generators

Employment: Massachusetts Office of State Planning and Stat Regional Planning Agencies have employment data by communit for the non-manufacturing sector (including government, but not the military) for 1975, and five year increments to 1990. These may be extrapolated to 2020. There is some difficulty however, in using this data directly to make consumption estimates in the commercial and institutional areas because the "Service" Employment sector overlaps both. If necessary, commercial services (e.g., hotel, restaurant, etc.) workers could be separated out leaving institutional services (in hospital, etc.). As noted in Table 6, employment is considered a usage generator in the major and non-major commercial and institutional subdivisions - this primarily sanitary water use by employees.

Daytime Population: An important generator of non-domestic water use is the average daytime population (other than employees) using the facilities. Such persons would includ inmates of institutions, patients, visitors at Federal and State recreational areas, visitors and temporary residents of hotels, and customers of restaurants. Although usually not directly available, the daytime population can be estimated from other measures such as number of hospital beds, numbers of guest rooms, number of seats in a restaurant, etc.

Whether and to what detail such factors need to be develope will have to be determined from some sensitivity analysis and selected case studies in which usage would be estimated strictly from employment or from a combination of employmen and daytime population data that is available.

As noted in Figure 1, daytime population is considered to b an important usage generation factor only for major commercial and institutional users. The large users and local water departments identified in the 1975 MDC Water Useage Study would be contacted by telephone, and in person as necessary, to collect this data, assess trends, and identify new factors to consider since the data was collected in 1972. Updates will be made as necessary and available.

Acreage, Sales: Primarily these generators relate to agricultural, golfcourse, public lands, and other uses such as gravel pit operations. An extensive data collection effort is not anticipated. Individual cases may need to be investigated in critical communities where a complete picture of consumption is required.

TABLE 6

NON-DOMESTIC
CONSUMPTION PROFILE

	COMMERCIAL: MAJOR	COMMERCIAL: NON-MAJOR	INSTITUTIONAL: MAJOR	INSTITUTIONAL: NON-MAJOR	AGRICULTRAL AND OTHER USERS
Usage Generators					
• Employment	X	X	X	X	
• "Day time"					
Population = e.g.					
Customers,	X				
Inmates,			X		
Patients,			X		
Temporary Visitors/ Residents			X		
• Acreage					X
• Sales					X
Use Factors					
• Use/Employees & Daytime population	X	X	X	X	
• Use/Acre					X
• Use/Sales $					X

Source: WFEM, 1980

Use Factors

Use Per Employee - The 1975 MDC Water Usage Study and other national studies developed use factors for non-major users based on the presumption that water consumption was primarily for sanitary purposes of employees. The 20 gallons per employee per day was assumed for non-major commercial users in the Water Usage Study (MDC, 1975) and should be reviewed. However, it is anticipated that national experience is applicable here and that further work on this question will be unnecessary for non-major users.

For major users, such as, hotels, restaurants, laundries, car washes, hospitals, and universities, use per employee will be further analyzed to the extent possible from available data and the community surveys to develop the factors most correlating with water consumption.

Use Per Daytime Population - This or related factors such as number of beds, rooms, seats, square feet of space, etc., may be required to develop reasonably accurate existing and future consumption estimates in the major non-domestic users sector. Because basic data needed to assess consumption from major non-domestic users is generally not available, the most efficient way is to go directly to the source. Although the numbers of possible contacts to be made are not large (and consumption information may be obtained from the local water departments) a sampling of these large water users may be employed.

Analysis will be required, however, to identify if use per employee is a reasonable usage factor and representative of the range of categories examined. If employment can be shown to directly relate to the scale of activity in similar establishments (restaurants for example), and if the scale of activity directly relates to water consumption for such establishments then use per employee will be a reasonable usage factor to adopt.

Use Per Acre, Use Per Dollars of Sales - Developing such use factors will be applied to agricultural and other uses that are identified as significant in some of the potential new MDC user communities; because this category is not currently a major user of the MDC system it remains to be seen to what extent these users may require future consideration. These should be handled individually as special cases as the analysis requires.

For agricultural irrigation in the Connecticut Valley, and other areas possibly impacted by alternatives (the Merrimack Valley, Plymouth County, for example) data can be interpolated from the U.S. Census of Agriculture and from the U.S. Water Resource Council's Second National Assessment.

INDUSTRIAL USE

Introduction

A second category of consumption data represented generally in Table 2 is industrial use. In previous projections of standardized 1990 water needs done for the Massachusetts Water Supply Study (WFEM, 1978) industry use was not separately analyzed, and was instead incorporated into a generalized recalculation of future water supply needs "using a methodology and revised population projection." The Corps of Engineers Water Demand Study for the Eastern Massachusetts Region concluded that "the best estimate of industrial demand would be to assume that it is a relatively constant percentage of average day use, over time, in any one town" (U.S. Army Corp. of Engineers, 1974). While these methods may have been appropriate to meet the needs of a consistent statewide assessment, it is not felt that such an approach alone would be adequate to meet the needs of this study. This conclusion is based on the following:

- Use projections have been highly controversial in the past and are likely to remain so (particularly in terms of conservation strategies). The projections must therefore be well founded and representative of the true situation. While an update of past projections using composite per capita use factors will be an important component of the demand/use work, it should therefore be complemented by other approaches and, where possible, more current in-depth data.

- Industrial use represents a significant portion of total water use and is not necessarily strongly correlated with either population growth or overall trends in average per capita per day usage. It represented an estimated 50 MGD of public water supplied for MDC communities in 1972 (Curran, 1975), (compared to 125.4 MGD domestic and 10.6 MGD commercial). However, total industrial usage (including private supplies) in MDC communities totaled about 272 MGD or more than double the domestic usage.

- Industrial use varies substantially from community to community (see Table 7) and should be separately appraised when evaluating specific supply augmentation strategies or specific alternatives to the MDC service area.

- Industrial use varies considerably from industry to industry (see Table 8) and the different rates of growth and trends in water intake for these different industries would have a significant effect on the future need for MDC water, both directly and indirectly. Table 9 shows projected state-wide industrial water needs based on 1972 intake per employee levels and state employement projections existing in 1974.

- A high percentage of the largest individual users of MDC water are industries (see Table 10). In 1972, 7 of the top 10 users in the MDC service area were industries and utilities, and 106 of the 215 top 5 users in each of 43 MDC communities were industries and utilities.

- Industrial use in both MDC and non-MDC communities has a significant dependence on non-metered private sources of water. Self-supplied industrial use in MDC communities amounted to an estimated 222 MGD (125 MGD for power generating facilities) in 1972 compared to 50 MGD from public supplies in these communities (Curran, 1975). These private sources, whether for cooling or process use, may be becoming inadequate (in terms of quantity or quality), and they may in some cases be sensitive to drought conditions. This could represent a further potential draw on MDC supplies.

- The effect on industrial use of conservation strategies (including reuse and recycling) will be very important to the assessment of potential impacts of these strategies in either average or crisis years.

- Overall per capita measures of water use are inadequate projection factors in communities with significant non-residential uses. For example, Boston's overall water use increased 24% during the 1960's while its population declined by 7% (U.S. Army Corp. of Engineers, 1974).

For these reasons, we have reviewed a number of other approaches and data sources which could help provide MDC with a better understanding of industrial water needs. These approaches would also provide information, so far unavailable from existing sources, on industrial usage and potential conservation reductions. This review is summarized in the next three parts of this memorandum.

Questions That Need To Be Answered

As an alternative to collapsing historical use projections into average per capita per day factors, we have reviewed the potential of other approaches that would provide further information more useful to the objectives of this study. In order to derive a more acceptable basis for decision making it is proposed to assess the sensitivity of use projections to alternative sets of assumptions (on rates of economic growth, on alternative MDC service areas, on water use

TABLE 7

INDUSTRIAL USE BY MUNICIPALITY

Water Usage Study - MDC (Curran Assoc.)

mgd		mgd	
12.42	Boston	0.43	Clinton
6.02	Worcester	0.42	Marlborough
4.25	Chicopee	0.31	Medford
4.13	Leominster	0.29	Melrose
3.99	Waltham	0.28	Malden
3.61	Everett	0.24	Lexington
3.36	Cambridge	0.23	Woburn
1.34	Framingham	0.19	Revere
1.33	Quincy	0.15	Wilbraham
1.26	Peabody	0.10	Belmont
0.97	Wakefield	0.08	Brookline
0.96	Somerville	0.07	Needham
0.87	Stoneham	0.05	Winthrop
0.85	Norwood	0.04	Canton
0.69	Newton	0.03	Southborough
0.52	S. Hadley F.D. #1	0.03	Chelsea

Water Supply Study - Eastern Mass. (Army Corps of Engineers)

mgd		mgd	
12.33	New Bedford	0.53	Walpole
4.52	Lynn	0.46	Foxborough
4.00	Attleboro	0.32	Poainville
3.27	Fall River	0.26	Franklin
2.60	Salem	0.25	Somerset
2.39	Taunton	0.15	Wellesley
1.56	Gloucester	0.15	Hingham
1.43	Brockton	0.15	Dedham/Westwood
0.85	Marshfield	0.13	Millis
0.80	Braintree	0.10	Plymouth
0.69	Danvers/Middleton	0.10	Dighton
0.61	Beverly	0.04	Stoughton
		0.04	Easton

TABLE 8

CURRENT STATE WATER USE
BY CLASSIFICATION

SIC	INDUSTRY	Employment (1000's) CofM 1973	OSP 1974	Census of Manufacturers Water Intake (Bgy) Total	Fresh from Public Sources	Unit Total Intake (gal/emp-day)
19	Ordinance		18.0			
20	Food	8.9	31.1	10.2	2.4	900
22	Textiles	9.0	28.9	5.0	0.7	470
23	Apparel		44.4			
24	Lumber	+	4.4	+	+	+
25	Furniture	+	10.0	+	+	+
26	Paper	12.3	32.3	68.9	10.1	5800
27	Printing		41.6			
28	Chemicals	7.7	18.6	13.3	7.5	2000
30	Rubber	11.7	34.2	8.9	1.3	710
31	Leather	1.9	24.1	1.7	1.4	190
32	Stone	4.3	13.4	2.0	0.9	410
33	Primary metals	3.9	17.7	1.8	0.7	280
34	Fabricated metals	10.1	47.5	6.4	1.4	370
35	Non-elec equipment	31.1	80.6	17.1	2.5	580
36	Elec equipment	40.2	103.0	4.3	3.5	110
37	Trans equipment	17.8	17.6	3.1	2.2	480
38	Instruments	17.1	41.6	6.8	1.5	450
39	Other	7.9	26.9	1.7	1.0	170

Source: WFEM, 1980

TABLE 9

PROJECTED WATER NEEDS

SIC	Industry	Employment (1000's) 1974	Employment (1000's) 1990	Water Use (Billions gallons/yr) Total Intake 1974	Total Intake 1990	Fresh Public 1974	Fresh Public 1990
20	Food	31.1	23.7	10.2	2.4	7.8	1.8
22	Textiles	28.9	10.0	5.0	1.7	0.7	0.2
26	Paper	32.3	46.7	68.9	98.9	10.1	14.5
28	Chemicals	18.6	23.1	13.3	16.9	7.5	9.5
30	Rubber	34.2	17.4	8.9	4.5	1.3	0.7
31	Leather	24.1	27.2	1.7	1.9	1.4	1.6
32	Stone, glass	13.4	18.0	2.0	2.7	0.9	1.2
34	Fabricated Metals	47.5	47.0	6.4	6.3	1.4	1.4
35	Non-elec. equip	80.6	52.5	17.1	11.1	2.5	1.6
36	Elec. equipment	103.0	72.7	4.3	2.9	3.5	2.4
37	Trans. equipment	17.6	19.9	3.1	3.5	2.2	2.5
38	Instruments	41.6	66.5	6.8	10.9	1.5	2.4
39	Other	26.9	28.2	1.7	1.7	1.0	1.0
		517.5	461.3	151.9	172.5	37.2	41.2

Source: Background Study for Massachusetts Water Supply Study, 1978

TABLE 10

LARGEST WATER USERS
IN MDC COMMUNITIES, 1972

Ten Largest Users

Name	Town	Total Annual Usage (MG) MDC + Community-Owned Supplies	Daily Usage (MGD)
Boston Edison	Boston	1,016.3	2.8
MIT	Cambridge	775.3	2.1
U.S. Rubber	Chicopee	765.4	2.1
Foster Grant	Leominster	762.8	2.1
U.S. Governement	Boston	670.8	1.8
Norton	Worcester	666.5	1.8
Raytheon	Waltham	554.0	1.5
Gillette Safety Razor	Boston	502.0	1.4
Harvard University	Cambridge	497.5	1.4
Boston Edison	Everett	420.7	1.0

Source: Curran, 1975

Note: See Appendix for detail on major industrial users by community.

trends and conservation, and on alternative private and public supplies).

A potential profile of existing and projected use that could characterize industrial water use in a way that would permit these assessments is illustrated below (see Table 11).

While this profile would provide a more adequate basis for projecting and displaying important aspects of industrial water use, the information is not readily available and our efforts have focused on what is available and how it can best be used to develop this general kind of profile. In terms of the key characteristics of industry that affect water use (Column A) we have tentatively listed three:

- SIC Code - the type of industry is obviously a key charcteristic affecting the future directions of industrial water use trends and the potential impact of conservation strategies (reuse, recycling, process change, etc.) and the need for supply augmentation. While it will not be necessary to utilize all SIC codes, it would be desirable at the two digit level to at least separate out the more water intensive users (e.g., food-20, chemicals-28, utilities, high technology firms and other special industries).

- Employment - for some industries, and for some water users, the level of employment represents a useful indicator. However, there are significant changes taking place affecting trends in water use per employee in different industries (see Figure 1) and we must incorporate these into future projections. For example, sanitary use in industry is most directly tied to employement, but process and cooling use are more tied to output and only indirectly to employment. Process and cooling use are also sensitive to water pollution control regulations and treatment requirements which may provide significant encouragement to recycling.

- Output - For the more water intensive industries, an understanding of the level of industry output (and the specific type of process/output) and trends will be important.

In terms of industrial water use (Column B), we have tentatively listed three types of use which would help characterize industrial water use where available:

- Sanitary Use - this use will probably be easiest to project and easiest to analyze in terms of conservation programs since it is similar for most industries and closely tied to employment.

TABLE 11

DESCRIPTIVE MATRIX FOR INDUSTRIAL USE

			(Col. A) Usage Generators		(Col. B) Use/Intake			(Col. C) Supply		
		SIC	employment	output	sanitary	process	cooling	MDC	other public	priva
1.	Fully served MDC	20							-	
		28							-	
		other							-	
2.	Partially served by MDC	20								
		28								
		other								
3.	Individual Add'l Commun- that may get MDC water	20								
		28								
		other								
3A	---	20								
		28								
		other								
3B	---	20								
		28								
		other								
3n	---	20								
		28								
4.	Groups of Impacted Communities	20								
		28								
		other								
4A	---	20								
		28								
		other								
4B	---	20								
		28								
		other								
4n	---	20								
		28								

Source: WFEM, 1980

- Process Use - this use is often facility specific but it would be desireable to identify major users and types of processes.

- Cooling Use - this use is also facility specific but it would again be desirable to identify major users.

In terms of the supply of water to industry (Column C), data is very sketchy but it would still be desirable to arrive at some estimate of the degree to which water is supplied to industrial users from:

- MDC;
- other public sources; and
- private sources.

Data Review and Evaluation

Corresponding to the proposed matrix of industrial use descriptors (Table 11), we have summarized below the data sources which might be most helful in characterizing the historical and projected entries in each of the three columns of this matrix--industrial water usage generators, industrial water use/intake, and industrial water supply.

1. Column A - Industrial Usage Generators (employment and output by SIC Code)

Water Use/Intake for an individual firm or for an entire industrial sector is usually considered to be a function of employment and/or output at that firm or in that sector. Potential sources of data on historical SIC code are summarized below:

- Historical employment data (1977, 1979) to be used are available from the State Division of Employment Security at the community level by two digit SIC code. However they are not published for all communities due to disclosure problems, and special arrangements would have to be made to use this data for the smaller communities. The 1977 state totals and a sample of what is published for each industry is included in Appendix 1. Historical data are also readily available on an annual basis at the county level from the U.S. Department of Commerce County Business Patterns.

- Historical industrial output data (gross value of shipments and value-added) are available from the U.S. Census of Manufacturers at the state and SMSA level and could be roughly allocated to individual communities on the basis of employment shares(assuming constant ratios of employees to output in each sector).

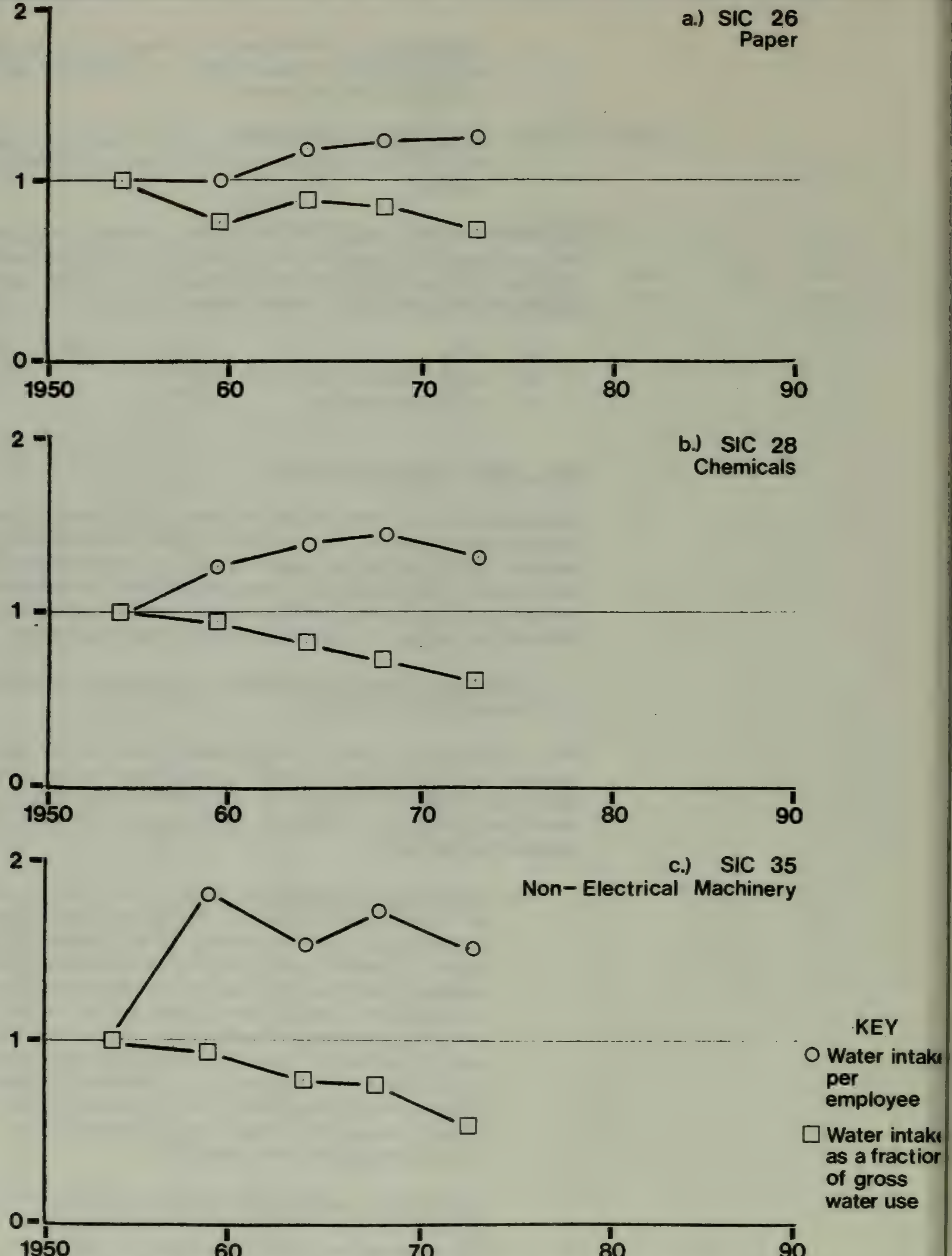


Figure 1 Trends in Water Use per Employee for Selected Industries

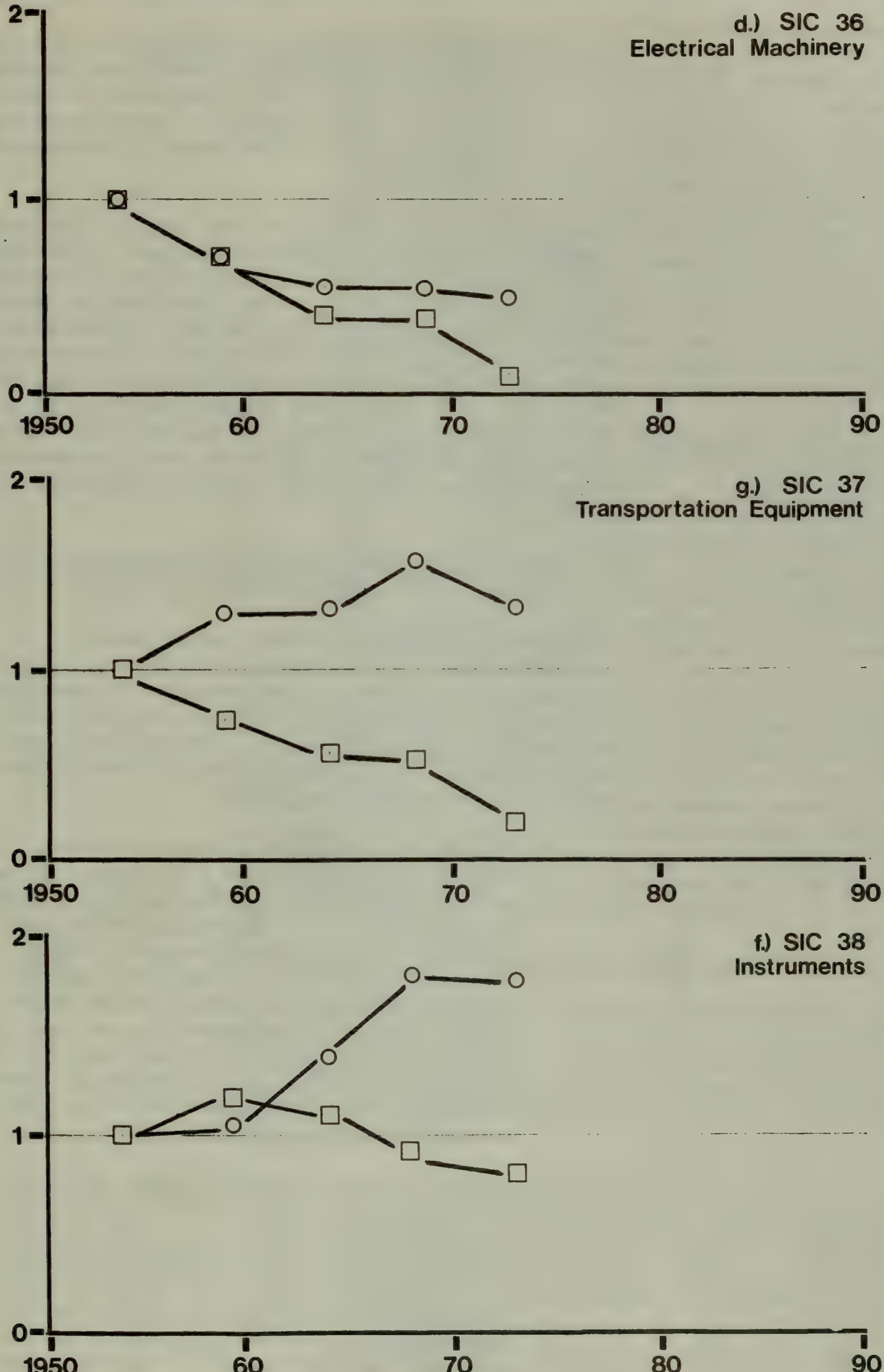


Figure 1 con. **Trends in Water Use per Employee for Selected Industries** [Continued]

- Industrial output projections are available at the national and regional level from the Bureau of Labor Statistics, but community or substate projections are generally unavailable unless one allocates them on the basis of employeemnt allocations.

In summary, while there are some gaps in the industrial employment and output data, it appears to be adequate for the purposes of both characterizing and projecting total industrial water use in broad groupings of communities. Existing gaps can generally be met through short-cut allocation procedures assuming we can access community level employment data at the Division of Employment Security. For individual communities it will prove a more difficult task to project and characterize industrial output and employment, and where such information is necessary, some additional survery data would probably be required.

2. Column B - Industrial Water Use/Intake (sanitary, process, and cooling use by SIC code)

The amount and type of water needed (and the appropriateness of different supplies) and the sensitivity of industsrial water use projections to conservation strategies, are largely a function of the process, cooling, or sanitary use to which the water is being put. Potential sources of data on historical and projected industrial water use are summarized below:

- Historical industrial use/intake data (1972, 1977) are available from the U.S. Census of Manufacturers at the State level by two digit SIC code (covering a reported 97% of industrial water use). The published data categorize use (process, cooling, sanitary) and also relate this reported intake/usage to employment, value added, and output and to public and private source (see illustrative tables in Appendix I). These data are not, however, available at the community level and some allocation method would have to be used to derive community level estimates based on these data.

  Other data on industrial water use at the community level have been collected by the MDC Sewer Division (the Black & Veatch survey) and where available provide detailed establishment by establishment data on industry type and water consumption (an illustrative Table for Arlington is included in the Apppendix). These data appear to be the best available at the community level but are only available at this time for some of the MDC sewer system communities (not yet including Boston, e.g.) and do not cover establishments in these communities who are not discharging to the sewer system.

Additional water consumption data for selected industrial establishments in violation of MDC rules are also available and indicate source, use and amount of water intake (illustrative tables for Malden are included in the Appendix). The 1975 Curran Report also provided a tabulation of metered industrial usage and estimated self-supplied industrial usage in each of the MDC communities for 1972 (see Appendix I). This report also provided tabulation of the water usage by all industries using in excess of 50,000 gpd in 1972 in the MDC communities (see Appendix 1). Some data on aggregate industrial water use from public water supplies only is also available and is discussed in the next section on industrial water use by source.

- Industrial Use/Intake Projections - The U.S. Army Corps of Engineers in their 1974 report attempted to project industrial water use to 1990 (see Appendix) using available employment projections and a similar effort was also undertaken as part of the 1978 Massachusetts Water Supply Study (WFEM, 1978)). We have not been able to identify any projections which have incorporated the more recently available industrial use data in a number of the communities.

In summary, the available data on historical industrial use varies by community but in most cases appear adequate to provide an updated basis for improved characterizations and projections of industrial water use/demand. The submission of data previously requested from member communities by the MDC sewer division would significantly reduce the magnitude of identified data gaps, and if such information is not made available, additional data collection would be necessary before proceeding to the analysis stage.

3. Column C - Industrial Water Supplies

The impact of currently changing industrial water usage on the MDC system will depend in large part on the degree to which industries depend on public or private water systems to meet their needs. Potential sources of data on historical and projected industrial water supplies are summarized below:

- Historical industrial water source data are available at the state level from the Census of Manufactures as described earlier, and at the community level from the Curran report, 1975 (for existing MDC communities). Some data are also available from the recent Black & Veatch survey although the responses are reportedly inaccurate in many cases. In addition, all users of MDC water now fill out a questionnaire estimating the gross consumption of public MDC water by industry. A similar questionaire is also filled out by both water companies and cities for the State Water Resources Commission.

- Projected industrial water source data do not appear to be available from sources other than individual industries and in some cases the communities in which they are located.

In summary, industrial water source data is the least adequate of the three sets of data postulated as being needed to adequately meet the objectives of this study. However, there is enough data available to provide a reasonable guide to the implications for MDC of future industrial uses. Some specific sampling data is necessary to determine the potential pressures that may be developing to shift industrial water supplies (e.g., well-contamination, inadequate quantity, inadequate yield).

D. Methods For Filling Identified Gaps and Analyzing Industrial Demand/Use

As noted above (C), there are a number of potential data sources for the three categories of data needed, and while there are some gaps, the problems appear to be more related to the use of multiple but incomplete data sets which may vary from community to community and may be inconsistent in terms of definitions, years, etc.

In terms of filling reported data gaps, we would at this time recommend that:

1. Procedures should be implemented to assure access to State Division of Employment Security data on industry employment by two digit SIC for all the communities identified.

2. Procedures should be initiated to obtain data on industrial water use previously requested from MDC sewer communities by MDC Sewer Division. Contacts should be made with non-MDC sewer communities to determine the potential availability of analagous data for all or major industrial water users.

3. For 100 largest industrial users of public water supplies in MDC communities (representing about 39 MGD in water use), additional telephone interviews should be conducted to determine trends and forecasts of water usage (including recycling/reuse) and estimated breakdown by types of use (process, cooling, sanitary).

4. Based on MDC sewer division data, selective follow up phone interviews should be conducted with major self-supplied industrial users to determine trends in adequacy of supplies (quantity/quality) and the potential for additional demands on MDC (or local) systems.

5. Where allocated shares of water usage from the Census of Manufacturers differs significantly from industrial usage reported by community to either MDC or WRC,

follow-up telephone contacts should be made with Water Department heads to explore reasons for variance.In terms of the analysis of industrial water use and demands the following approach is recommended:

- Develop profile of industry in existing and potential MDC communities as characterized by employment and industrial output (using State Division of Employment Security data and Census of Manufacturers data for existing profiles and using adjusted/allocated Office of State Planning and Department of Commerce Data for projected profiles).

- Develop profile of industrial water use (and trends where possible) in identified groups of communities for the 1970's. (Using MDC data, water district reports, and industry specific data from MDC sewer division and other sewer departments.)

- Update projections of industrial water usage based on composite per capita per day methods as previously employed in State Water Supply Study (WFEM, 1978), (using more recent data now available from MDC and other communities for the late 1970's).

- Project industrial water usage based on industry-specific trends and projections (using revised OSP employment projections, allocated output projections, and industry-specific information on water use trends and forecasts).

- Estimate potential industrial demands on MDC water supplies based on alternative assumptions or communities to be served.

- Assess sensitivity of industrial use and demand estimates to different conservation strategies and trends and to different rates/types of industrial growth and water usage. Also review potential adequacy of non-MDC supplies to meet industrial water demands of various types.

Appendix I

TABLE 10-2

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
MDC MEMBERS		
Arlington	No. Union St. Playground	5.8
	Symmes Hospital	5.6
	Town Hall	3.8
	Hillsdale Ave. Nursing Home	3.2
	Arlmont Laundry	2.3
Belmont	Cambridge Plating Inc.	38.1
	McLean Hospital	30.4
	Oakley Country Club	17.0
	Police Dept.	7.8
	Lucatelli Real Estate	5.1
Boston	Boston Edison Co.	1,016.3
	U. S. Government	670.8
	Gillette Safety Razor	502.8
	Harvard University	298.4
	American Sugar	227.5
Brookline	Dy-Dee Service Inc.	29.1
	Pine Manor Jr. College	18.8
	Boston Hospital for Women	15.3
	Putterham Meadows Municipal Golf Course	11.1
	Brook House	9.9
Cambridge	M.I.T.	775.3
	Harvard University	497.5
	Polaroid	371.7
	United Carr Fastener Corp.	290.6
	Cambridge Gas & Light Co.	155.4
Canton	Plymouth Rubber Co.	15.2
	Mass. Hospital	13.7
	Duval Corp.	9.0
	Groverton Paper Co.	6.3
	Dean S. Luce School	4.9
Chelsea	Soldiers Home	50.9
	Chelsea Naval Hospital	37.5
	Monkiewicg	12.1
	New England Produce Center	10.1
	American Optical	9.0

Source: MDC Water Usage Study, 1975

TABLE 10-2 (Continued)

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
Everett	Boston Edison	420.7
	Monsanto Chemical Co.	417.0
	General Electric	193.7
	Exxon Co.	146.2
	Avco Corp.	54.6
Lexington	Hanscom Field U.S.A.F.	283.5
	Itek	184.4
	V. A. Hospital	59.3
	Raytheon	25.6
	Instrumentation Laboratory	15.0
Lynnfield Water District	Colonial Restaurant	3.7
	Ship Restaurant	3.3
	Town Lyme Restaurant	3.0
	Bali Hai Restaurant	2.5
	Kenwood Restaurant	2.0
Malden	Converse Rubber	73.2
	Malden Hospital	59.9
	Friend Bros.	14.8
	Mass. Electric	12.9
	M.D.C. Pool	3.7
Marblehead	Town Incinerator	42.6
	Marblehead Laundry	4.9
	Arizshiam	4.9
	Super Market	2.8
	Hood Molded	2.3
Medford	Federal Bond Board	26.0
	Cain Co.	19.9
	General Chemical	18.6
	Contain Corp.	18.6
	Lawrence Memorial Hospital	17.3
Melrose	Trimont Asphalt	76.8
	Melrose Wakefield Hospital	20.9
	Bakular-Transitron	16.9
	Joseph Sawtell	14.3
	Melrose Dev. Hockey Club	4.6

TABLE 10-2 (Continued)

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
Milton	M.D.C. (Total)	18.8
	Curry College	11.9
	Milton Academy	11.5
	Milton Hospital	11.4
	Hendries Inc.	4.8
Nahant	Rock Ledge	1.9
	Jesmond	1.6
	Tides Restaurant	.8
	Country Club	1.0
	Bayside	.5
Needham	Sylvania	13.3
	International Equipment	12.4
	Glover Memorial Hospital	9.6
	First National Stores	9.1
	William Carter Co.	8.1
Newton	Boston College	74.9
	Newton Incinerator	66.1
	St. Regis Paper Co.	50.7
	Marriott	44.8
	Veinite Corp.	41.9
Norwood	Bird & Son, Inc.	70.4
	Polaroid Corp.	70.4
	Northrop	69.6
	New London Mills	35.2
	M. T. Acquiring	30.7
Peabody	Lawrence Leather Co.	95.8
	Orgelas Leather Co.	50.7
	United Finishing Co.	47.9
	Webster Industries	47.9
	U. S. M. Corp.	39.0
Quincy	General Dynamics Corp.	278.4
	Proctor & Gamble	70.4
	Raytheon	67.9
	Quincy City Hospital	35.6
	Boston Edison Co.	25.6

TABLE 10-2 (Continued)

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
Revere	Ogden Suffolk Downs Inc.	17.2
	Revere Racing Association	8.4
	Geri-Care Nursing Center	5.6
	Grover Manor Hospital	5.6
	Gertrude Feldman	3.3
Saugus	Valles Restaurant	11.3
	Hill Top Restaurant	8.6
	Kowloon Restaurant	6.9
	Hospital plus Annex	7.5
	Chateau de Ville	4.8
Somerville	Finast	108.7
	Tufts University	60.9
	Cott Bottling	60.1
	Swift & Co.	54.1
	Boston & Maine Co.	44.9
Stoneham	Atlantic Gelatin	290.9
	New England Memorial Hospital	31,8
	Sunnyhurst Dairy	13.9
	Stoneham Laundry	13.6
	Bear Hill Country Club	8.4
Swampscott	General Glove Inn	9.8
	Athanas	4.9
	Preston Inn	2.5
	Gibbs Oil	1.7
	Pewter Pot	1.6
Wakefield	Transitron	355.1
	Wakefield Eng.	12.6
	Wakefield Redi-Mix	10.5
	Wakefield Bearing	9.2
	Kytron	8.0
Waltham	Raytheon	553.9
	Polaroid	417.2
	Brandeis University	139.7
	Canada Dry	86.5
	General Tel. & Tel.	77.8

TABLE 10-2 (Continued)

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
Watertown	Unitrode Transitron Products	63.7
	Watertown Arsenal	62.9
	The Barry Corp.	29.9
	Haartz-Mason, Inc.	23.4
	Highway Dept.	22.9
Weston	Regis College	12.8
	Pinebrook Golf Course	5.9
	Cambridge School	4.4
	Weston Nursing Home	3.0
	Junior High School	2.7
Winchester	Winchester Hospital	20.8
	Whitten	6.1
	First National Stores	5.1
	J. H. Winn	4.8
	Winchester Country Club	4.1
Winthrop	M.D.C. Treatment Plant	26.3
	Duval Industries	20.2
	Winthrop Comm. Hospital	4.8
	Nursing Home	3.8
	Winthrop Golf Club	3.3
Woburn	Tanners Degreasing	74.3
	Alpha Industries	37.8
	New England Plastics	24.3
	High School	18.7
	Johnson's Bros. Greenhouse	18.1
NONMEMBER COMMUNITIES		
Chicopee	U. S. Rubber	765.4
	Westover Air Force Base	447.6
	A. G. Spaulding	447.5
	Hampden Brewing	159.8
	Industrial Building	82.9
Clinton	Marine Plastics	67.5
	Van Brodie Milling Co.	57.4
	I. T. T. Supernant Mfg. Co.	21.7
	Phoenix Plastics Co.	12.5
	Clinton Hospital	11.5

TABLE 10-2 (Continued)

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
Framingham	Denison Mfg. Co.	205.2
	General Motors	198.6
	Sealtest Foods	69.5
	Cushing Hospital	26.7
	Sisters of St. Joseph's	23.1
Leominster	Foster Grant	762.8
	Borden	242.9
	Solar Chemical	137.0
	Synthetic Materials	56.3
	Commonwealth Plastics	51.7
Marlborough	Stop & Shop	105.0
	Zar-X	34.5
	I. Likon Corp.	15.0
	Holiday Inn	9.7
	Marlborough Hospital	8.9
Northborough	Lawrence Candle Factory	10.2
	Algonquin Regional School	4.4
	Thornton Nursing Home	2.1
	Charles Trombetta Florist	2.2
	Bay State Circuits Inc.	2.1
South Hadley Fire District #1	Scott Graphics, Inc.	92.4
	Nonotuck Manufacturing Co.	57.8
	Texon Inc.	28.7
	South Hadley High School	2.3
	City Parks & Playgrounds	1.8
Southborough	L. B. Darling, Inc.	12.8
	St. Mark's School	7.5
	Refrig. Storage Center, Inc./ Hendrics Ice Cream	5.4
	Fay School	3.4
	Data General	2.7
Wilbraham	Stateline Potato Chip Co.	37.8
	Friendly Ice Cream Corp.	15.8
	Monson Academy	13.7
	Minnechaug Regional High School	8.4
	Wilbraham Industrial Park	3.6

TABLE 10-2 (Continued)

FIVE LARGEST WATER USERS FOR EACH COMMUNITY

Community	Name of User	Total Annual Usage (MG)
Worcester	Norton	666.5
	Wyman Gorden Co.	166.6
	Reed & Prince Mfg. Co.	128.7
	U. S. Steel	106.2
	Johnson Steel & Wire Co.	105.8

Appendix I-2

Table 1

The Commonwealth of Massachusetts
Manufacturing Industries
Classified by Size of Employment
1977

Sic Code*	Industry	Firms#	Employment#
36	Electrical and Electronic Machinery	657	93,800
35	Machinery except Electrical	1,555	83,500
34	Fabricated Metal Products	1,065	51,300
38	Instruments	431	50,500
23	Apparel	741	42,600
27	Printing and Publishing	1,434	41,600
37	Transportation Equipment	153	33,000
30	Rubber and Plastic Products	445	29,700
26	Paper and Allied Products	321	29,600
20	Food and Kindred Products	577	28,800
22	Textile Mill Products	324	27,600
31	Leather and Leather Products	335	22,900
28	Chemicals and Allied Products	355	17,700
33	Primary Metals	246	14,400
32	Stone, Clay, Glass and Concrete Products	309	11,300
25	Furniture and Fixtures	328	8,100
24	Lumber and Wood Products	363	5,200
29	Petroleum Refining and Related Products	38	1,400
21	Tobacco Manufacturers	2	30

* SIC: Standard Industrial Classification, 1972

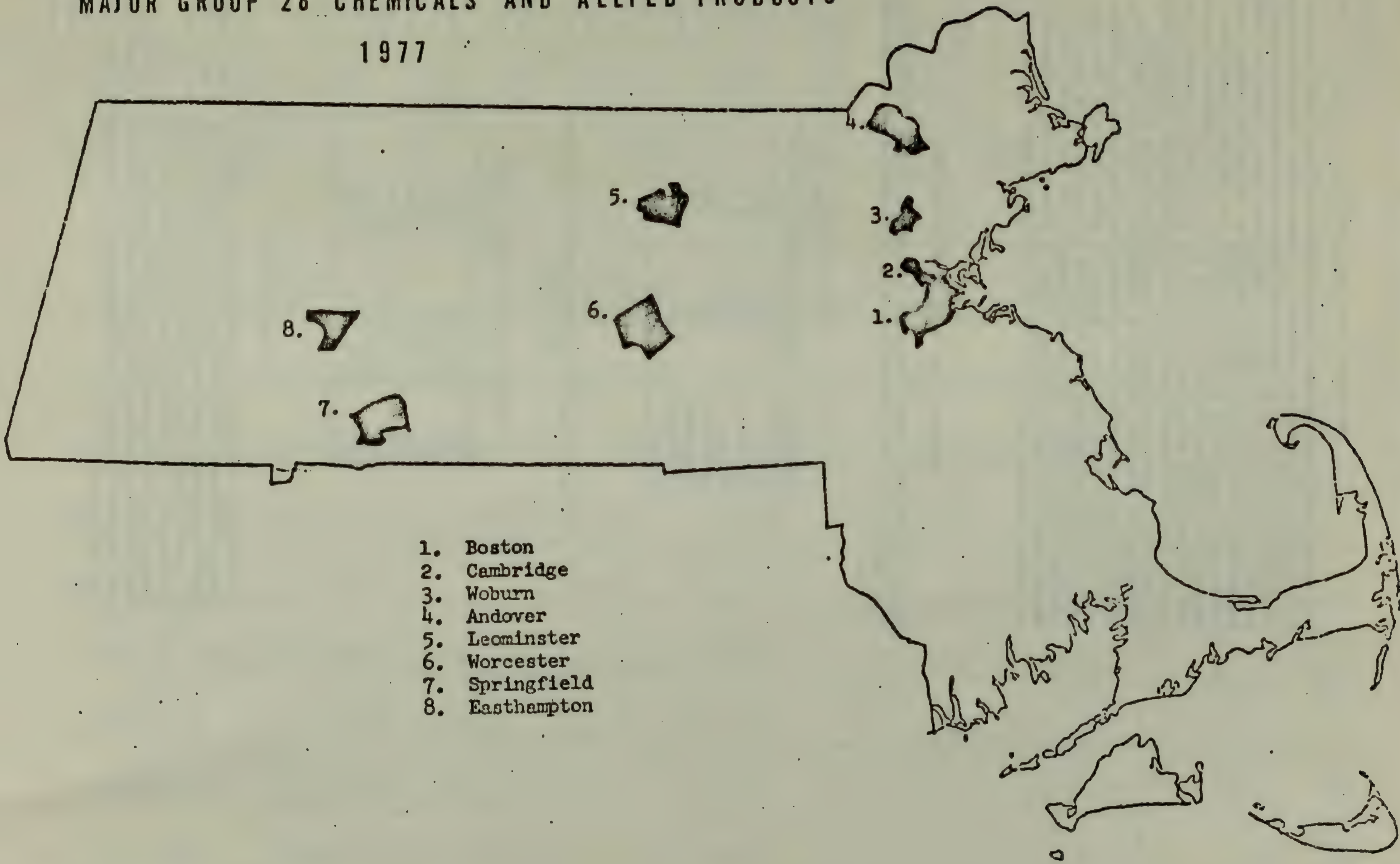
\# Employment and Wages Subject to Massachusetts Employment Security Law, 1977 ES-202 Report.

Source: Industrial Profile of Manufacturing Industries in Massachusetts 1970-1977, Massachusetts Division of Employment Security.

CENTERS OF PRODUCTION

MAJOR GROUP 28 CHEMICALS AND ALLIED PRODUCTS

1977



The Major Group As A Whole

This major group includes establishments producing basic chemicals, and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: (1) basic chemicals such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture such as synthetic fibers, plastics materials, dry colors, and pigments; (3) finished chemical products to be used for ultimate consumption such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries such as paints, fertilizers, and explosives. The mining of natural rock salt is classified in mining industries. Establishments primarily engaged in manufacturing nonferrous metals and high percentage ferroalloys are classified in Major Group 33; silicon carbide in Major Group 32; baking powder, or other leavening compounds, and starches in Major Group 20; and artist's colors in Major Group 39. Establishments primarily engaged in packaging, and bottling of purchased chemical products, but not engaged in manufacturing chemicals and allied products, are classified in trade industries.

Locations With Significant Employment

The cities and towns listed below had at least 3 percent of total statewide employment in this industry based on 1977 annual average employment levels.

Location	Employment	Percent of Statewide Total
Springfield	2,463	13.9
Boston	1,604	9.1
Worcester	938	5.3
Andover	742	4.2
Cambridge	695	3.9
Easthampton	637	3.6
Leominster	568	3.2
Woburn	539	3.0

Average Annual Employment and Annual Payroll Statewide

Year	Annual Payroll (in 000's)	Average Annual Employment
1970	$182,357.2	19,200
1971	187,742.3	18,600
1972	191,218.0	18,200
1973	211,872.0	18,700
1974	229,032.5	18,800
1975	261,090.4	19,500
1976	261,547.1	18,200
1977	270,514.3	17,700

Industry Trends

This industry, traditionally characterized as highly automated, has fluctuated between 18,000 and 20,000 for the past twenty years. While industry employment declined as did both the state and national level, by 4 percent during the recession year of 1975, 1976 saw most of that loss recouped. In fact, over the 5 year period from 1972 to 1977, chemicals and allied products was the only nondurable goods sector to experience any growth at all, albeit only 3.3 percent. Primarily, gains have been reported in firms producing plastic resins, drugs, soaps and cosmetics.

TABLE 3B. Water Intake, by Purpose and Kind, for Geographic Areas and Major Industry Groups: 1973

(Billion gallons)

SIC code	Geographic division, State, and major industry group	Total water intake	Fresh water							Brackish water	
			Total	Process	Cooling and condensing			Sanitary service	Boiler feed and other uses	Total	Process
					Steam electric power generation	Air conditioning	Other				
	United States, total	15,034.3	12,194.9	3,772.4	1,980.1	278.0	5,344.3	206.6	610.0	1,395.6	68.7
	New England Division	670.1	598.0	268.6	216.0	7.5	71.1	17.3	17.2	7.9	(D)
	Maine	169.2	165.7	123.7	15.5	.3	11.3	(D)	(D)	(D)	-
20	Food and kindred products	2.9	2.9	1.4	(D)	-	.9	.2	(D)	-	-
22	Textile mill products	3.2	3.2	2.6	-	-	.1	-	.4	-	-
26	Paper and allied products	155.9	155.9	117.6	(D)	.2	9.1	(D)	2.7	-	-
28	Chemicals and allied products	3.8	.2	(D)	-	-	-	-	(D)	(D)	-
30	Rubber and miscellaneous plastics products	1.0	1.0	(D)	-	-	.8	-	(D)	-	-
31	Leather and leather products	1.0	1.0	.9	-	-	-	-	.1	-	-
	New Hampshire	26.0	(D)	(D)	(D)	.2	(D)	.6	(D)	(D)	-
20	Food and kindred products	.9	.9	.3	-	-	(D)	(D)	-	-	-
22	Textile mill products	.9	.9	.7	-	-	-	-	.1	-	-
26	Paper and allied products	21.4	21.4	17.1	1.6	-	1.5	.1	1.0	-	-
32	Stone, clay, and glass products	.2	.2	.1	-	-	.1	-	-	-	-
35	Machinery, except electrical	.3	.3	-	-	(D)	(D)	(D)	-	-	-
36	Electric and electronic equipment	.3	.3	(D)	-	(D)	.1	-	-	-	-
	Vermont	6.5	6.5	4.2	(D)	.3	.5	(D)	.6	-	-
20	Food and kindred products	.3	.3	.2	-	-	-	-	-	-	-
26	Paper and allied products	4.1	4.1	2.9	(D)	-	-	-	(D)	-	-
35	Machinery, except electrical	.1	.1	-	-	-	-	-	-	-	-
36	Electric and electronic equipment	.6	.6	.4	-	(D)	(D)	-	-	-	-
	Massachusetts	151.9	12[illegible].7	45.4	48.8	3.7	21.7	3.1	4.9	4.1	(D)
20	Food and kindred products	10.2	3.8	1.5	-	-	1.4	.3	.5	(D)	-
22	Textile mill products	5.0	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
26	Paper and allied products	68.9	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
28	Chemicals and allied products	13.3	10.2	5.0	-	.2	4.2	.1	.7	(D)	-
29	Petroleum and coal products	.4	.4	.3	-	-	.1	-	-	-	-
30	Rubber and miscellaneous plastics products	8.9	(D)	(D)	-	(D)	(D)	(D)	(D)	(D)	-
31	Leather and leather products	1.7	1.7	1.6	-	-	-	-	-	-	-
32	Stone, clay, and glass products	2.0	1.3	.4	-	.2	.6	-	-	(D)	(D)
33	Primary metal industries	1.8	1.8	.9	-	-	.7	.1	.1	-	-
34	Fabricated metal products	6.4	6.4	5.4	-	.2	.6	.1	.1	-	-
35	Machinery, except electrical	17.1	(D)	(D)	(D)	(D)	(D)	(D)	(D)	-	-
36	Electric and electronic equipment	4.3	4.3	1.3	-	.7	1.7	.5	.2	-	-
37	Transportation equipment	3.1	2.2	.5	-	(D)	(D)	.5	.2	-	-
38	Instruments and related products	6.8	6.8	1.0	(D)	(D)	.4	.3	.1	-	-
39	Miscellaneous manufacturing industries	1.7	1.7	.5	-	-	1.1	.1	-	-	-
	Rhode Island	14.4	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	-
20	Food and kindred products	1.0	1.0	.2	-	(D)	(D)	-	-	-	-
22	Textile mill products	2.2	2.2	1.8	-	-	-	.1	.2	-	-
28	Chemicals and allied products	1.5	1.5	.6	-	-	.7	-	.2	-	-
32	Stone, clay, and glass products	.8	(D)	(D)	(D)	-	(D)	(D)	-	(D)	-
33	Primary metal industries	4.4	4.4	3.8	-	-	(D)	.1	(D)	-	-
34	Fabricated metal products	.3	.3	(D)	-	-	(D)	-	-	-	-
35	Machinery, except electrical	.3	.3	.1	-	-	.1	.1	-	-	-
36	Electric and electronic equipment	.5	.5	.1	-	-	.2	.1	-	-	-
39	Miscellaneous manufacturing industries	.6	.6	.2	-	.1	.2	.1	.1	-	-
	Connecticut	302.2	258.0	68.0	(D)	2.5	31.1	2.7	(D)	(D)	(D)
20	Food and kindred products	1.0	(D)	(D)	-	(D)	(D)	(D)	(D)	(D)	-
22	Textile mill products	3.3	3.3	.9	(D)	.1	(D)	.1	.2	-	-
28	Chemicals and allied products	47.9	(D)	(D)	-	(D)	(D)	(D)	(D)	(D)	-
30	Rubber and miscellaneous plastics products	13.4	(D)	(D)	-	(D)	(D)	(D)	(D)	(D)	-
32	Stone, clay, and glass products	1.1	(D)	(D)	-	-	(D)	-	(D)	(D)	(D)
33	Primary metal industries	15.5	14.5	(D)	(D)	.1	5.6	.4	.5	(D)	(D)
34	Fabricated metal products	7.4	7.4	3.2	(D)	.2	(D)	.5	.2	-	-
35	Machinery, except electrical	3.9	3.9	2.0	-	.8	.9	.2	.3	-	-
36	Electric and electronic equipment	1.9	1.9	.6	-	.2	.6	.2	.2	-	-
38	Instruments and related products	.6	.6	.3	-	.1	.1	.1	-	-	-
39	Miscellaneous manufacturing industries	2.4	2.4	1.0	(D)	-	(D)	.1	.1	-	-
	Middle Atlantic Division	2,355.5	2,053.8	497.2	304.7	43.2	1,097.1	35.0	76.2	136.2	3.6
	New York	513.8	466.1	135.3	18.1	25.5	254.7	11.9	20.3	(D)	(D)
20	Food and kindred products	24.7	13.0	5.2	.2	.2	4.1	1.1	2.1	(D)	-
22	Textile mill products	4.0	4.0	3.3	-	-	.3	.1	.2	-	-
26	Paper and allied products	64.8	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
28	Chemicals and allied products	126.4	94.7	9.5	.3	1.6	76.8	2.0	4.5	(D)	(D)
29	Petroleum and coal products	20.4	20.4	.5	-	-	19.3	.1	.6	-	-
30	Rubber and miscellaneous plastics products	5.1	5.1	1.9	(D)	(D)	2.2	.1	.4	-	-

See footnotes at end of table.

TABLE 2B Gross Water Used and Water Intake, by Source and Kind, for Geographic Divisions, States, and Major Industry Groups: 1973

SIC code	Geographic division, State, and major industry group	Establishments reporting water intake: Number of employees[2] (1,000)	Value added by manufacture[1] (million dollars)	Value of shipments[1] (million dollars)	Total (number)	Gross water used, including recirculated (billion gallons)	Water intake, by kind: Total (billion gallons)	Fresh water, by source: Total (billion gallons)	Public water system (billion gallons)	Company systems: Surface (billion gallons)	Ground (billion gallons)	Tidewater (billion gallons)
	UNITED STATES, TOTAL	7083.0	172760.3	389717.6	10668	46965.3	15028.3	12198.9	1638.9	8693.1	1514.6	348.7
	NEW ENGLAND DIVISION	473.0	9374.2	17139.2	766	1156.7	670.1	598.0	81.9	490.0	25.9	.5
	MAINE	34.8	594.3	1313.4	80	407.9	169.2	165.7	8.1	153.1	(D)	(D)
20	FOOD AND KINDRED PRODUCTS. . .	5.6	85.9	233.8	25	10.0	2.9	2.9	(D)	1.0	(D)	-
22	TEXTILE MILL PRODUCTS.	5.1	56.4	118.4	12	3.5	3.2	3.2	.8	2.4	-	-
24	LUMBER AND WOOD PRODUCTS . . .	(D)	(D)	(D)	2	(D)	(D)	(D)	-	-	-	-
26	PAPER AND ALLIED PRODUCTS. . .	15.0	310.0	703.8	23	386.3	155.9	155.9	3.6	148.8	(D)	(D)
28	CHEMICALS AND ALLIED PRODUCTS.	.5	9.0	18.6	3	4.0	3.8	.3	.3	-	-	-
30	RUBBER, MISC. PLASTICS PROD. .	1.6	26.0	48.2	3	1.5	1.0	1.0	.4	.6	-	-
31	LEATHER AND LEATHER PRODUCTS .	1.5	21.7	60.8	4	1.0	1.0	1.0	.4	.6	-	-
33	PRIMARY METAL INDUSTRIES . . .	(D)	(D)	(D)	1	(D)	(D)	(D)	(D)	-	-	-
34	FABRICATED METAL PRODUCTS. . .	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
36	ELECTRIC, ELECTRONIC EQUIP . .	(D)	(D)	(D)	3	(D)	(D)	(D)	(D)	-	-	-
37	TRANSPORTATION EQUIPMENT . . .	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
	NEW HAMPSHIRE	21.2	376.0	666.7	53	68.4	26.0	(D)	(D)	(D)	(D)	-
20	FOOD AND KINDRED PRODUCTS. . .	.5	30.4	74.5	6	(D)	.9	.9	(D)	-	(D)	-
22	TEXTILE MILL PRODUCTS.	2.5	33.4	56.5	8	.9	.9	.9	.3	.5	-	-
26	PAPER AND ALLIED PRODUCTS. . .	4.5	71.0	163.9	13	49.6	21.4	21.4	(D)	20.8	(D)	-
28	CHEMICALS AND ALLIED PRODUCTS.	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
30	RUBBER, MISC. PLASTICS PROD. .	(D)	(D)	(D)	3	(D)	(D)	(D)	(D)	-	-	-
31	LEATHER AND LEATHER PRODUCTS .	(D)	(D)	(D)	3	(D)	(D)	(D)	(D)	(D)	-	-
32	STONE, CLAY, GLASS PRODUCTS. .	1.3	19.1	29.6	5	.3	.2	.2	.1	.1	-	-
33	PRIMARY METAL INDUSTRIES . . .	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
34	FABRICATED METAL PRODUCTS. . .	(D)	(D)	(D)	1	(D)	(D)	-	-	-	-	-
35	MACHINERY, EXCEPT ELECTRICAL .	3.8	72.7	99.8	6	.3	.3	.3	.2	-	-	-
36	ELECTRIC, ELECTRONIC EQUIP . .	1.7	24.6	38.3	4	.4	.3	.3	.2	-	.1	-
37	TRANSPORTATION EQUIPMENT . . .	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
38	INSTRUMENTS, RELATED PRODUCTS.	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	(D)	-	-
	VERMONT	15.2	252.1	617.9	37	11.9	6.5	6.5	1.7	4.4	.4	-
20	FOOD AND KINDRED PRODUCTS. . .	.4	4.7	47.0	4	.4	.3	.3	.2	-	-	-
24	LUMBER AND WOOD PRODUCTS . . .	(D)	(D)	(D)	1	(D)	(D)	(D)	-	(D)	-	-
25	FURNITURE AND FIXTURES	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
26	PAPER AND ALLIED PRODUCTS. . .	1.6	44.9	82.5	9	9.0	4.1	4.1	.1	4.0	-	-
28	CHEMICALS AND ALLIED PRODUCTS.	(D)	(D)	(D)	1	(D)	(D)	-	-	-	-	-
30	RUBBER, MISC. PLASTICS PROD. .	(D)	(D)	(D)	1	(D)	(D)	(D)	(D)	-	-	-
31	LEATHER AND LEATHER PRODUCTS .	(D)	(D)	(D)	1	(D)	(D)	-	-	-	-	-
32	STONE, CLAY, GLASS PRODUCTS. .	(D)	(D)	(D)	2	(D)	(D)	(D)	-	(D)	-	-
33	PRIMARY METAL INDUSTRIES . . .	(D)	(D)	(D)	1	(D)	(D)	-	-	-	-	-
34	FABRICATED METAL PRODUCTS. . .	(D)	(D)	(D)	1	(D)	(D)	(D)	(D)	-	(D)	-
35	MACHINERY, EXCEPT ELECTRICAL .	1.2	20.1	33.3	3	.1	.1	.1	.1	-	-	-
36	ELECTRIC, ELECTRONIC EQUIP . .	4.7	75.6	268.1	4	.7	.6	.6	(D)	-	(D)	-
37	TRANSPORTATION EQUIPMENT . . .	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
38	INSTRUMENTS, RELATED PRODUCTS.	(D)	(D)	(D)	2	(D)	(D)	(D)	-	(D)	-	-
39	MISC. MANUFACTURING INDUSTRIES.	(D)	(D)	(D)	1	(D)	(D)	-	-	-	-	-
	MASSACHUSETTS	189.8	4158.0	7219.3	299	255.5	151.9	127.7	37.2	78.7	(D)	(D)
20	FOOD AND KINDRED PRODUCTS. . .	8.0	199.0	697.5	36	10.6	10.2	3.8	2.4	.9	.5	-
22	TEXTILE MILL PRODUCTS.	9.0	131.2	285.7	27	5.1	5.0	(D)	(D)	(D)	(D)	-
24	LUMBER AND WOOD PRODUCTS . . .	(D)	(D)	(D)	1	(D)	(D)	(D)	(D)	-	(D)	-
25	FURNITURE AND FIXTURES	(D)	(D)	(D)	1	(D)	(D)	(D)	(D)	-	-	-
26	PAPER AND ALLIED PRODUCTS. . .	12.3	231.4	481.2	51	112.0	88.9	(D)	(D)	(D)	(D)	-
28	CHEMICALS AND ALLIED PRODUCTS.	7.7	298.9	523.3	19	22.1	17.3	10.2	7.5	(D)	(D)	-
29	PETROLEUM AND COAL PRODUCTS. .	(D)	(D)	(D)	4	(D)	(D)	(D)	(D)	-	(D)	-
30	RUBBER, MISC. PLASTICS PROD. .	11.7	251.8	429.3	27	14.4	8.9	(D)	(D)	(D)	(D)	-
31	LEATHER AND LEATHER PRODUCTS .	1.9	20.0	48.3	6	1.7	1.7	1.7	1.4	.1	.2	-
32	STONE, CLAY, GLASS PRODUCTS. .	4.3	99.8	151.1	7	2.6	2.0	1.3	.9	(D)	(D)	-
33	PRIMARY METAL INDUSTRIES . . .	3.9	71.1	163.6	19	2.0	1.8	1.8	.7	.9	.2	-
34	FABRICATED METAL PRODUCTS. . .	10.1	260.5	359.0	17	7.8	6.4	6.4	1.4	4.7	.3	-
35	MACHINERY, EXCEPT ELECTRICAL .	31.1	822.9	1170.0	26	27.0	17.1	(D)	(D)	(D)	(D)	-
36	ELECTRIC, ELECTRONIC EQUIP . .	40.2	721.8	1124.3	29	6.8	4.3	4.3	3.5	.5	.3	-
37	TRANSPORTATION EQUIPMENT . . .	17.6	396.4	823.1	7	26.7	3.1	2.2	2.2	-	-	-
38	INSTRUMENTS, RELATED PRODUCTS.	17.1	499.9	780.1	15	13.8	8.8	8.8	1.5	4.8	(D)	(D)
39	MISC. MANUFACTURING INDUSTRIES.	7.9	134.1	190.3	10	2.0	1.7	1.7	1.0	-	.7	-
	RHODE ISLAND	32.2	538.2	958.6	65	21.4	14.5	(D)	(D)	(D)	(D)	-
20	FOOD AND KINDRED PRODUCTS. . .	2.0	56.9	97.0	4	1.3	1.0	1.0	.3	-	.7	-
22	TEXTILE MILL PRODUCTS.	3.4	41.7	66.8	13	2.2	2.2	2.2	.7	1.3	.2	-
26	PAPER AND ALLIED PRODUCTS. . .	(D)	(D)	(D)	2	(D)	(D)	(D)	-	(D)	-	-
28	CHEMICALS AND ALLIED PRODUCTS.	1.5	24.0	53.3	5	3.3	1.5	1.5	.7	.8	-	-
29	PETROLEUM AND COAL PRODUCTS. .	(D)	(D)	(D)	1	(D)	(D)	(D)	(D)	(D)	-	-
32	STONE, CLAY, GLASS PRODUCTS. .	1.2	23.3	31.9	3	1.0	.8	(D)	(D)	-	(D)	-
33	PRIMARY METAL INDUSTRIES . . .	5.6	102.4	236.5	11	5.5	4.4	4.4	.9	3.2	.2	-
34	FABRICATED METAL PRODUCTS. . .	1.3	14.3	21.8	6	.4	.3	.3	.3	-	-	-
35	MACHINERY, EXCEPT ELECTRICAL .	4.5	69.9	109.9	6	.3	.3	.3	(D)	-	(D)	-
36	ELECTRIC, ELECTRONIC EQUIP . .	5.5	77.2	129.0	5	.8	.5	.5	.4	-	.1	-
38	INSTRUMENTS, RELATED PRODUCTS.	(D)	(D)	(D)	2	(D)	(D)	(D)	(D)	-	-	-
39	MISC. MANUFACTURING INDUSTRIES.	4.7	90.7	143.9	9	1.0	.6	.6	.6	-	-	-
	CONNECTICUT	185.7	3455.6	6363.3	230	391.5	302.2	258.0	25.7	225.0	(D)	(D)
20	FOOD AND KINDRED PRODUCTS. . .	4.1	78.8	192.8	13	2.3	1.0	(D)	(D)	-	(D)	-
22	TEXTILE MILL PRODUCTS.	6.4	107.4	203.5	18	3.4	3.3	3.3	.8	2.5	-	-
26	PAPER AND ALLIED PRODUCTS. . .	(D)	(D)	(D)	10	(D)	(D)	(D)	(D)	(D)	(D)	(D)
28	CHEMICALS AND ALLIED PRODUCTS.	7.0	163.2	349.4	12	59.6	47.9	(D)	(D)	(D)	(D)	-
29	PETROLEUM AND COAL PRODUCTS. .	(D)	(D)	(D)	1	(D)	(D)	-	-	-	-	-
30	RUBBER, MISC. PLASTICS PROD. .	8.8	148.2	264.6	17	16.7	13.4	(D)	(D)	(D)	(D)	-
32	STONE, CLAY, GLASS PRODUCTS. .	3.0	56.4	103.8	6	1.3	1.1	(D)	(D)	-	-	-

See footnotes at end of table.

Appendix I-4

INDUSTRIAL INVESTIGATION REPORT

[__/___ ___-_]

Page______ of _____

Investigation Date ____/____/____ Municipality __________

Zip Code __________

Investigators:

MDC ______________

B&V ______________

Industry Name: ____________________

Address: ____________________

____

____

____

Billing Address: ____________________

____

____

Weekly Hrs. of Operation: ____________

Contact: ____________________

No. of Employees: ____________

Title: ____________________

Name of Scavenger: ____________

Telephone: __________ Ext. ______

Type of Scavenger: ____________

SIC No's: ______ ______ ______ ______ ______

MDC Discharge Codes: ______ ______ ______ ______ ______

Wastewater Constituent Codes: ____________________

Raw Materials: ____________________

Products: ____________________

Industrial Category: ______ Pretreatment Present: ______ Type of Pretreatment: ______

(Note: Provide Explanation for Missing Information.)

....

(Check all that apply)

Discharge to: Nut Island System ____________ Deer Island System ____________

Water Source: MDC ________ Surface ________ Wells ________ Town ________ Other ______

Wastewater Disposal: Local Sewer ______(Separate ____;Combined ______;Unknown__________)

MDC (Direct Connection) _____ Subsurface or ground_____ Surface water course_____

Left: Permit application _____ Rules & Regulations _____

Instruction sheet ____ Scavenger List _____

....

Reviewer's Comments:

Source: MDC Sewer Division Survey

Revised 11/6/79

NAME OF COMPANY	TYPE OF INDUSTRY	PROCESS SIC CODE	WATER CONSUMPTION (gpd)	DISCHARGE TO SEWER (gpd)	OTHER DISCHARGE	CHARACTERISTIC OF WASTE	DISCHARGE SIC CODE	PRE-TREATMENT	TYPE OF PRETREATMENT	COMMENTS

Source: MDC Sewerage Division, data and records reviewed at MDC, May 2, 1980.

ARLINGTON *

NAME OF COMPANY	TYPE OF INDUSTRY	PROCESS SIC CODE	WATER CONSUMPTION (gpd)	COMMENTS
AMW Corp 78 Bow Street	bookbinding machinery	3552	955	Investigated: 7-31-79
A.N.Z. Corp. Inc. 78 Bow Street	wooden furniture	2511	included with AMW Corp. one meter for both	7-31-79
Advance Machine Shop 32 Mill Lane	job machine shop	3599	included with Atlas Van Line 1 meter for bo	7-31-79
Aram's Printing Service 92-94 Warren Street	commercial custom printing	2731	255	8-14-79
Arlington Lithographic 6 Schouler Court	commercial offset printing	2731	1,208	8-2-79
Associated Woodworkers Inc. 1165R Mass Ave.	custom wood furniture	2511	*	8-8-79
Atlas Van Lines 22 Mill Street	trucking - moving storage	4214	200	8-14-79
Atlantic Wire & Iron Works Inc 26 Gardner Street	security, rooling doors wire & iron applications	3496	59	7-31-79
Atlantic Roofing & Sky light Works 30 Park Ave	mfg all kinds of hatches	3449	** 6,713	8-14-79
Babcock-Davis Associates Inc. 50 Lowell Street	mfg flagpoles hatchways, sidewalk doors and smoke vents	3444 3446	** included with Boston Metal D	8-2-79
Bedlam Brass Refinishers 1167 Mass. Ave.	brass refinisher	3471	*	8-8-79
Boston Metal Door 60 Lowell Street	mfg of metal doors and elevator cabs	3442	** 3,499	8-14-79
Boston Screen & Sash Co. 91 Mystic St.	assembly of aluminum windows	3442	492	7-31-79

* Columns deleted represent discharge data that is proprietary.

Source: MDC sewerage Division, data and records, reviewed at MDC May 2, 1980.

NAME OF COMPANY	TYPE OF INDUSTRY	PROCESS SIC CODE	WATER CONSUMPTION (GPD)	COMMENTS
Brigham's Inc. a div of Jewel Co., Inc 30 Mill Street	mfg ice cream syrups, beef patties & ham steaks	2024 2011 2065	18,420	Investigated: 8-14-79
Copy-Rite Copy Center 1379 Mass Ave.	copy center & lithographic printing	2752	627	8-15-79
Ralph Gerbrands Co. Inc. 8 Beck Rd.	mfg Eng Lab & Sci research equipment	3811	59	7-31-79
H.A.F. Inc./The Charter Press Printers & Bank Service Bureau 5 Forest ST.	commercial printers	2751 2752	141	8-8-79
Habitat Woodshop 1165 R Mass Ave.	custom furniture subcontractor	2511	*	8-8-79
Layne New York Co. 15 Ryder St.	wells pumps & water treatment	1711	138	8-15-79
Maran Printing Services Inc. 1406 Mass Ave.	commercial printing offset	2751 2752	141	8-8-79
N.E. Telephone Co. Motor Vehicle Dept. Hobbs Ct.	vehicle parking & maint. garage	7525	556	8-17-79
Verne Q. Powell Flutes Inc. 70 Bow Street	mfg. handmade flutes & picolos Ag & Au	3931	379	7-31-79
Alexander Preston Furniture Design & Woodworking 1165 Mass Ave	custom unfinished furniture	2511	*	8-15-79
The Schawm Mill Preservation Trust 17 Mill Lane	historical craft center	3944	*	8-9-79
Malcolm G. Stevens Inc.P.O. Box 145 78 Summer St	picture frames foundry supplies & equip.	2499 5051	131	8-2-79
Wilfert Bros. Wood-Working Co., Inc 22 Prentiss St.	custom furniture	2511	33	8-15-79

NAME OF COMPANY	TYPE OF INDUSTRY	PROCESS SIC CODE	WATER CONSUMPTION (gpd)	COMMENTS
Chester A. Little Co. 348 Mass. Ave.	commercial printing and lithograph	2731	756	investigated: 9-14-79
Pappas Furniture Refinishing Co. 81 Mystic St.	furniture refinishing	7641	298	9-14-79

NOTES:
Brigham's Inc. mfg ice cream and uses

CITY OF MALDEN

As of December 21, 1979

Industries originally in violation now in compliance with Metropolitan District Commission's Rules and Regulations:

1. Ace-lon Corporation
2. Eastern Laquer Corporation
3. Louise's Home Style Ravioli Co.

Industries not in compliance with Metropolitan District Commission's Rules and Regulations:

1. American Aluminum Window Corporation
*2. F. M. Callahan's Plating Company
3. Colorgraphics, Inc.
4. Continental Can Co.
5. Globe Nickel Plating Co., Inc.
6. Palmer Mfg. Corporation
7. Rexart
8. Wolf & Munier, Inc.

*No change in status from Industrial Waste Report #9 June 28, 1979

Source: Industrial Waste Report #10, MDC Sewer Division, 1979

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date ____________

If different from stated address, please correct when answering

A) Name of Company, Ace-Lon Corporation

B) Business Address, 950 Eastern Avenue Malden, MA 02148
No. Street Town or City Zip Code

Telephone Number, 322-7121 3. Years at present location ____________

Type of industry, Manufacturing

A) Standard Industrial Classification Index Number, P 3079

B) Major products or services: Plastic Bags

C) List type and quantity of chemicals used annually in process-(if applicable):
1. Lactol Spirits
2. Super Naphthacite
3. Alcohol
4. Solvents

Daily water consumption, 3,170 gpd cu. ft/day or gal/day

A) Source of supply, City of Malden

Total volume of waste discharged into Public Sewer, 3,170 gal/day

Other discharge:- Sub-surface or ground, ____________ gal/day

Surface waters, ____________ gal/day

Scavenger services, (type/quantity) ____________

NOTE: If seasonal, please indicate No

A) Characteristics of waste discharge-(if known): Domestic Waste Only

all uncontaminated cooling water is now being recirculated.

B) Is pretreatment practiced? ________Yes ___X___No

If "Yes" please indicate type:

a) Separators or Traps________________

b) Screening________________

c) Sedimentation________________

d) Coagulation and/or Precipitation________________

e) Other (specify)________________

C) Is pretreatment planned? ________Yes ___X___No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________Yes ______No
If "Yes" indicate number of copies________________

Name of Company Representative preparing this return:

Name: Paul Gentile Date 12/14/79

Title: President

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-8989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date ________________

1. If different from stated address, please correct when answering
   A) Name of Company, American Aluminum Window Corp.
   B) Business Address, 767 Eastern Avenue Malden, MA 02148
   No. Street Town or City Zip Code
2. Telephone Number, 324-8650 3. Years at present location ________
4. Type of industry, Manufacturing
   A) Standard Industrial Classification Index Number, 3442
   B) Major products or services: Manufacturing storm windows, doors

   C) List type and quantity of chemicals used annually in process-(if applicable):

5. Daily water consumption, 1,990 gpd cu. ft/day or gal/day
   A) Source of supply, City of Malden
6. Total volume of waste discharged into Public Sewer, 1,990 gal/day
   Other discharge:- Sub-surface or ground, ________ gal/day
   Surface waters, ________ gal/day
   Scavenger services, (type/quantity) ________

NOTE: If seasonal, please indicate No
A) Characteristics of waste discharge-(if known): Domestic Waste and uncontaminated cooling water.

B) Is pretreatment practiced? ________Yes ___X___No

If "Yes" please indicate type:

a) Separators or Traps________________

b) Screening________________

c) Sedimentation________________

d) Coagulation and/or Precipitation________________

e) Other (specify)________________

C) Is pretreatment planned? ________Yes ________No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________Yes ___X___No
If "Yes" indicate number of copies________________

Name of Company Representative preparing this return:

Name: James Minieri Date 12/14/79

Title: Manager

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-5989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date________________

f different from stated address, please correct when answering

) Name of Company, Continental Can Co.

) Business Address, 650 Eastern Avenue Malden, MA 02148
No. Street Town or City Zip Code

Telephone Number, 322-6820 3. Years at present location________

Type of industry, Manufacturing

A) Standard Industrial Classification Index Number, 3542

B) Major products or services: metal cans and containers

C) List type and quantity of chemicals used annually in process-(if applicable):

Daily water consumption, 25,000 gpd cu. ft/day or gal/day

A) Source of supply, City of Malden

Total volume of waste discharged into Public Sewer, 25,000 gal/day

Other discharge:- Sub-surface or ground,________gal/day

Surface waters,________gal/day

Scavenger services, (type/quantity)________

NOTE: If seasonal, please indicate________

A) Characteristics of waste discharge-(if known): domestic waste and uncontaminated cooling water

B) Is pretreatment practiced? ________Yes ___X___No

If "Yes" please indicate type:

a) Separators or Traps________________

b) Screening________________

c) Sedimentation________________

d) Coagulation and/or Precipitation________________

e) Other (specify)________________

C) Is pretreatment planned? ________Yes ________No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________Yes ________No
If "Yes" indicate number of copies________________

Name of Company Representative preparing this return:

Name: Arthur N. Teneriello Date 10/25/78

Title: Plant Supervisor

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-8989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date ____________________

If different from stated address, please correct when answering

A) Name of Company, Eastern Lacquer Corporation

B) Business Address, 1100 Eastern Avenue Malden, MA 02148
No. Street Town or City Zip Code

Telephone Number, 322-8000 3. Years at present location ________

Type of industry, Manufacturing

A) Standard Industrial Classification Index Number, 2851

B) Major products or services: Enamals, Lacquers, urethanes

C) List type and quantity of chemicals used annually in process-(if applicable):
Butyl Acetate
Butanol
Isopropyl Alcohol
Acetone

Daily water consumption, indeterminate cu. ft/day or gal/day

A) Source of supply, City of Malden and private well

Total volume of waste discharged into Public Sewer, ________ gal/day

Other discharge:- Sub-surface or ground, ________ gal/day

Surface waters, ________ gal/day

Scavenger services, (type/quantity) solvent recovery

NOTE: If seasonal, please indicate ________

A) Characteristics of waste discharge-(if known): domestic waste only

all uncontaminated cooling water is now being discharged to a dry well.

B) Is pretreatment practiced? ________Yes ___X___No

If "Yes" please indicate type:

a) Separators or Traps________________

b) Screening________________

c) Sedimentation________________

d) Coagulation and/or Precipitation________________

e) Other (specify)________________

C) Is pretreatment planned? ________Yes ___X___No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________Yes ________No
If "Yes" indicate number of copies________________

Name of Company Representative preparing this return:

Name: Burton Liebman Date 12/14/79
Title: Manager

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-8989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date__________

I different from stated address, please correct when answering

Name of Company, Louise's Home Style Ravioli Co.

Business Address, 370 Commercial Street Malden, MA 02148
No. Street Town or City Zip Code

Telephone Number, 324-7600 3. Years at present location__________

Type of industry, Manufacturing

Standard Industrial Classification Index Number, 2098

Major products or services: Macaroni products

) List type and quantity of chemicals used annually in process-(if applicable):

Daily water consumption, 64,000 gpd cu. ft/day or gal/day

) Source of supply, City of Malden

Total volume of waste discharged into Public Sewer, 40,000 gal/day

Other discharge:- Sub-surface or ground, __________ gal/day

Surface waters, __________ gal/day

Scavenger services, (type/quantity) __________

NOTE: If seasonal, please indicate No

) Characteristics of waste discharge-(if known): Domestic waste only. All uncontaminate cooling water has been redirected to the storm drainage system.

B) Is pretreatment practiced? ____X____ Yes ________ No

If "Yes" please indicate type:

a) Separators or Traps ________

b) Screening ________

c) Sedimentation ____X____

d) Coagulation and/or Precipitation ________

e) Other (specify) ________

C) Is pretreatment planned? ________ Yes ________ No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________ Yes ________ No
If "Yes" indicate number of copies ________

Name of Company Representative preparing this return:

Name: Leo Sutera Date 12/14/79

Title: Manager

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-5989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date ____________

If different from stated address, please correct when answering

A) Name of Company, Palmer Mfg. Corp.

B) Business Address, 243 Medford Malden, MA 02148

No. Street Town or City Zip Code

Telephone Number, 321-0480 3. Years at present location ____

Type of industry, Machine Shop

A) Standard Industrial Classification Index Number, P3724

B) Major products or services: Machine parts for aircraft jet engines

C) List type and quantity of chemicals used annually in process-(if applicable):

Daily water consumption, 2,200 gpd cu. ft/day or gal/day

A) Source of supply, City of Malden

Total volume of waste discharged into Public Sewer, 2,200 gal/day

Other discharge:- Sub-surface or ground, ____ gal/day

Surface waters, ____ gal/day

Scavenger services, (type/quantity) ____

NOTE: If seasonal, please indicate No

A) Characteristics of waste discharge-(if known): Domestic waste and uncontaminated cooling water.

B) Is pretreatment practiced? ___X___Yes ________No

If "Yes" please indicate type:

a) Separators or Traps________________________________

b) Screening________________________________

c) Sedimentation________________________________

d) Coagulation and/or Precipitation________________________________

e) Other (specify)________________________________

C) Is pretreatment planned? ________Yes ________No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________Yes ________No
If "Yes" indicate number of copies________________________________

Name of Company Representative preparing this return:

Name: Ray Gosselin Date 12/14/79

Title: V. P. & Sales Mgr.

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-5989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date________________

I different from stated address, please correct when answering

Name of Company, Rexart

Business Address, 54 Winter Malden 02148
No. Street Town or City Zip Code

lephone Number, 321-2420 3. Years at present location________

ype of industry, Printer

) Standard Industrial Classification Index Number, 2893

) Major products or services: Inks for graphic arts - off-set lithographers

) List type and quantity of chemicals used annually in process-(if applicable):

aily water consumption, 4,400 gpd cu. ft/day or gal/day

) Source of supply, City of Malden

otal volume of waste discharged into Public Sewer, 4,400 gal/day

ther discharge:- Sub-surface or ground, ________ gal/day

Surface waters, ________ gal/day

Scavenger services, (type/quantity) ________

IOTE: If seasonal, please indicate No

) Characteristics of waste discharge-(if known): domestic waste and uncontaminated cooling water

B) Is pretreatment practiced? __________Yes ____X____No

If "Yes" please indicate type:

a) Separators or Traps________________________________

b) Screening________________________________

c) Sedimentation________________________________

d) Coagulation and/or Precipitation________________________________

e) Other (specify)________________________________

C) Is pretreatment planned? __________Yes __________No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? __________Yes ________No
If "Yes" indicate number of copies________________________________

Name of Company Representative preparing this return:

Name: Dave Albert Date 12/14/79

Title: Plant Supervisor

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-8989)

THE COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION

Due Date________________

If different from stated address, please correct when answering

A) Name of Company, Wolf & Munier, Inc.

B) Business Address, 775 Eastern Avenue Malden 02148

No. Street Town or City Zip Code

Telephone Number, 321-4300 3. Years at present location________

Type of industry, Manufacturing

A) Standard Industrial Classification Index Number, 3444

B) Major products or services: ducts, pipe

C) List type and quantity of chemicals used annually in process-(if applicable):

Daily water consumption, 2,100 gpd cu. ft/day or gal/day

A) Source of supply, City of Malden

Total volume of waste discharged into Public Sewer, 2,100 gal/day

Other discharge:- Sub-surface or ground,________gal/day

Surface waters,________gal/day

Scavenger services, (type/quantity)________

NOTE: If seasonal, please indicate________

A) Characteristics of waste discharge-(if known): domestic waste and uncontaminated cooling water

B) Is pretreatment practiced? ________Yes ____X____No

If "Yes" please indicate type:

a) Separators or Traps________________

b) Screening________________

c) Sedimentation________________

d) Coagulation and/or Precipitation________________

e) Other (specify)________________

C) Is pretreatment planned? ________Yes ____X____No, if "Yes", indicate implementation date:

____

7. Would you like additional copies of the "Rules and Regulations concerning Discharge of Waste"? ________Yes ________No
If "Yes" indicate number of copies________________

Name of Company Representative preparing this return:

Name: George Oppel Date 12/14/79

Title: Vice President

Please return to:

METROPOLITAN DISTRICT COMMISSION
SEWERAGE DIVISION
20 SOMERSET STREET
BOSTON, MASSACHUSETTS 02108

Att: Noel Baratta
Chief Sanitary Engineer
(Telephone: 727-5989)

Appendix I-6

OUTLINE OF MUNICIPAL WATER RESOURCES MANAGEMENT PLAN

WATER SUPPLY ELEMENT
(Due December 31, 1979)

1. Municipality Reporting (______________________________)
City, Town

   a. Unit Responding (______________________________)
   Water Dept., Selectmen, Town Engineer, etc.

2. Community Demographic Data

   a. 1975 State Census Figure (________________)

   b. Regional Planning Commission Projections (______) (______) (______)
   1980 1985 1990

   c. Other Population Projections (______) (______) (______) (______)
   1980 1985 1990 -

   Source ______________________________

3. Demand Data* (Expressed in m. g. d. or fraction thereof)

   a. Current avg. day demand ________ mgd; est. 1985 avg. day demand _____ mgd

   b. Current max. day demand ________ mgd; est. 1985 max. day demand _____ mgd

   c. % of population served by central supply system ________ %   est. 1985% of population served by central supply ________ %

   d. Per capita consumption ($\frac{a}{c \times pop.}$) ________________ gpcd

   e. What proportion of the avg. day demand (3 a.) do you attribute to domestic water use? ________ %
   Combined domestic and commercial use ? ________________ %

   f. Of the remaining water not used for domestic or commercial purposes, please estimate the proportion attributed to the following:

   Industrial ____________ % (current)   ____________ % (1985)

   Agricultural ____________ % (current)   ____________ % (1985)

* Does your municipal system supply water for all or part of another town? ______
If yes, explain ______________________________

Source: State Water Resources Commission

Unmetered Municipal Uses ______________% ______________%
current 1985

Undertermined Loss ______________%

Other consumption, specify ______________________________

g. Is there significant commercial, industrial or agricultural water consumption within the community which is not provided by the central supply system? ______________________________

If yes, can you estimate the amount and list the source of supply? __________

____

____

4. Supply Data (Currently available sources)

a. Sources of central supply - Percent furnished by

Municipally Owned Surface Supplies ______________%

Municipally Owned Wells ______________%

*Regional or Joint Supply System ______________%

**Private Water Company (ies) ______________%

* ** If all or a portion of the community is served by a regional system or private water supply company please supply name(s) of these sources

____

____

b. Municipally Owned Surface Supply - (List name, acreage and volume or instream withdrawal parameters for rivers) ______________________________

____

____

____

Safe yield of surface supply ______________mgd - How was figure

derived? ____

Type of treatment provided surface supply ____________________

____

c. Municipally Owned Sub-Surface Supply - (Wells - List name or #, type, and pumping capacity)

Safe yield of wells ____________ mgd - How was figure derived? __________

____

Type of treatment provided - subsurface supply ____________________

____

d. What are the present water quality problems? ____________________

____

____

What future problems are anticipated? ____________________

____

____

e. Watershed or well site protection afforded - (e.g., zoning, acquisition, local health codes, etc.) ____________________

____

____

____

f. Abandoned or discontinued sources (Reservoirs or wells)

____

____

1. Reason for abandonment ______________________________

____

2. Present use (if dedicated to new purpose) ______________

____

3. Possibility of renovation ______________________________

____

g. Municipal Sewage Treatment - check one - (yes______) (none______)

If yes,

1.) Type of Treatment ______________________

2.) Discharge Point - (Receiving Watershed) ____________

5. Water Conservation Program

a. Percent of users now metered ____________%

b. Rate structure in use, (e.g. increasing decreasing block rate - seasonal - other)

Specify ____

c. What efforts to reduce losses and consumption are planned or in place?*

	In Place	Planned
1. Universal metering	______	______
2. Leak detection studies	______	______
3. Preventative maintenance	______	______

* If a conservation plan has been adopted, please include a copy.

4. Changes of rate structure ____________ ____________

5. Encouragement of water saving devices ____________ ____________

6. Ban of non-essential uses ____________ ____________

7. Protecting or upgrading sources ____________ ____________

8. Water conservation education program ____________ ____________

9. Other ____________ ____________

6. Augmentation Plans

a. Projected additional yield required by 1985 or later time frame.

(____________ mgd) (____________ mgd)
1985 year?

1. Basis of projection - population to be served ____________

per capita consumption ________ gpcd ________ yr.

b. Identified new or expanded sources

Surface

1. Location, (include a locus map showing site and watershed, attach data sheet to plan with following information:

2. Acreage and volume or instream withdrawal parameters.

3. Water treatment needed.

4. Environmental effects of withdrawal for water use (e.g., interbasin diversion, effect on flow regime, changes in land use, etc.)

5. Safe yield and how derived.

c. Identified Groundwater Sources

1. Location - (include a locus map showing watershed and potential aquifer - attach data sheet with following information).

2. Type of wells and planned pump capacity.

3. Treatment needed and plans for aquifer protection

4. Environmental effects of withdrawals (e.g., interbasin diversion, effect on stream flow, changes in land use, etc.)

5. Safe yield estimate and how derived.

d. Other potential sources of water supply to be investigated__________

____

____

____

e. Has there been public participation in water supply planning in your community?

Hearings____________________

Public Meetings____________________

Other____________________

f. Additional Comments

____

____

____

____

Prepared By:

Address____________________

____

Tel. No. ____________________

OUTLINE OF WATER RESOURCES MANAGEMENT PLAN
(Due December 31, 1979)

From the: ______________________________
Water Company

To the: Massachusetts Water Resources Commission
Division of Water Resources
Leverett Saltonstall Building - 100 Cambridge Street
Boston, Massachusetts, 02202

1. Area/Population Served

(a) Territory covered by charter rights; ______________________________

____

(b) Cities or towns in which water was dispensed in 1979; (1) ____________

(2) ____________ (3) ____________ (4) ____________

(c) For each community listed above, complete the following information:

Community (1) ____________ Estimated total population of territory

covered by franchise within this city/town ____________

Estimated population actually supplied with water ________

Percent metered ______

Residential Use: Avg. Day Demand ________ mgd. ; Max Day Demand ______ mg.

gallons per yr. domestic ____________ mg.

Commercial: No. of Services ______; gals. per yr. supplied ____________ mg.

Industrial: No. of Services ________; gals. per yr. supplied ____________ mg.

Municipal: No. of Services ________; gals. per yr. supplied ____________ mg.

Institutional: No. of Services ______; gals. per yr. supplied ____________ mg.

Agricultural: No. of Services ______; gals. per yr. supplied ____________ mg.

Other; ____________ ;gals. per yr. supplied ____________ mg.

Total supplied ____________ mg.
(1979)

Community (2)____________________, Estimated total population of territory covered by franchise within this city/town________________

Estimated population actually supplied with water________percent metered______%

Residential use: Avg. Day Demand________mgd. Max day Dem.________mgd.

gallons per year domestic____________mg.

Commercial - No. of services__________gals. per year supplied__________mg.

Industrial - No. of services__________gals. per year supplied__________mg.

Municipal - No. of services__________gals. per yearsupplied__________mg.

Institutional - No. of services__________gals. per year supplied__________mg.

Agricultural - No. of services__________gals. per year supplied__________mg.

Other____________________gals. per year supplied__________mg.

Total supplied____________________
(1979)

Remaining communities where water is supplied and distributed by your company. (List town, pop. served, amts. of water supplied as above and current annual total.)

____

____

____

____

(d) If water is sold in bulk to a municipality, water district, residential complex, or other water company for distribution, service, and billing, please list the names of receiving agencies and the amounts of water per year supplied by your company.

____

____

____

____

(e) Are the water amounts given in 1, (d) above, separate and additional to any amounts listed under the various communities in 1, (c) or were they included in total for each community? ____________________

2. Supply - Sources and Yield

(a) Surface Supplies - (Give the name and location of lakes or reservoirs, rivers or streams from which water is currently drawn. State the ownership or if leased, the terms of the leases. List the surface area when full and the full capacity in gallons of reservoirs and/or withdrawal rights and pumping capacity from streams.)

____

____

____

____

____

____

What is the current safe yield of existing surface supplies? ____________ mgd.

(b) Ground Water (List the type and location of wells, galleries and springs owned or leased for water supply purposes and current pumping capacity.)

____

____

____

____

What is the safe yield of existing sub-surface supplies? ____________ mgd.

3. Projected Supply and Demand

(a) Does the water company plan expanded coverage or additional services in the future?

____

____

(b) For each community where expanded water service will be provided by the year 1990, please estimate the water company's projections as follows:

City/Town__________ Est. 1990 pop. to be served__________ Est. 1990 avg. day dem.________ Est. 1990 max. day dem.______

Other Uses______________________________ Est. 1990 gals. needed__________

(c) Are existing company owned or leased water supply sources sufficient to meet anticipated 1990 requirements?

(d) If not - what additional safe yield capactiy will be required? (Note: if ample surface storage is available, 1990 avg. day demand for all consumption may be used. If dependent on ground water sources, max. day demand should be provided.)

Additional safe yield required by 1990____________________m

(e) Methods by which increased demand could be met.

(1990)

1) Raising capacity of existing reservoirs______ Est. add. yield__________mg

2) Construction of new surface supplies______ Est. add. yield__________mg

3) Development of new wells or groundwater systems__________

Est. add. yield__________mg

4) Increased pumping capacity__________ Estimated effective add. delivery__________mg

5) Additional transmission or distribution capacity__________

Est. effective add. delivery__________mg

6) Rehabilitation of abandoned or discontinued sources__________

Est. add. yield__________mg

7) Other____________________ Est. add. yield__________mg

Water Quality

(a) What are the present water quality problems? ____________

(b) What types of treatment are presently provided ____________

(c) What future problems are anticipated? ____________

Water Conservation Program

(a) Precent of users now metered ____________ %

(b) Rate structure in use, (e.g. increasing decreasing block rate - seasonal - per connection- other,

Specify ____________

(c) What efforts to reduce losses and consumption are planned or already in place?

	In Place	Planned
1) Universal metering	____	____
2) Leak detection studies	____	____
3) Preventive maintenance	____	____
4) Changes of rate structure	____	____
5) Encouragement of water saving devices	____	____
6) Ban of non-essential uses	____	____
7) Protection or upgrading sources	____	____
8) Water conservation education program	____	____
9) Other ____		____

6. Additional Comments

____

____

____

____

____

Prepared by ______________________

Address ______________________

____

Tel. No. ______________________

INDUSTRIAL WATER USAGE BY COMMUNITY - 1972

COMMUNITY	METERED INDUSTRIAL WATER USE FROM MDC AND COMMUNITY - OWNED SUPPLIES: ANNUAL INDUSTRIAL USE, MILLIONS OF GALLONS	AVERAGE DAILY INDUSTRIAL USE, GPD	PER CAPITA INDUSTRIAL USE, GPCD POP. SERVED	TOTAL USAGE FROM MDC AND COMMUNITY-OWNED SUPPLIES, GPD	PER CENT INDUSTRIAL USE	ESTIMATED SELF-SUPPLIED INDUSTRIAL USE: AVERAGE DAILY USE, GPD	TOTAL INDUSTRIAL USE: MDC, COMMUNITY-OWNED AND SELF-SUPPLIED, GPD
MEMBER							
ARLINGTON	0	0	0.	6987000	0.	142000	142000
BELMONT	38	105000	4.	2794000	4.	0	105000
BOSTON	4546	12421000	20.	143975000	9.	69494000	81915000
BROOKLINE	29	80000	1.	7628000	1.	0	80000
CAMBRIDGE	1229	3359000	34.	22346000	15.	94610000	97969000
CANTON	15	42000	2.	1760000	2.	340000	382000
CHELSEA	12	33000	1.	3673000	1.	0	33000
EVERETT	1323	3616000	86.	7619000	47.	7000000	10616000
LEXINGTON	87	239000	7.	4508000	5.	0	239000
LYNNFLD W D	0	0	0.	347000	0.	0	0
MALDEN	100	276000	5.	7293000	4.	360000	636000
MARBLEHEAD	0	0	0.	2136000	0.	0	0
MEDFORD	112	308000	5.	8551000	4.	0	308000
MELROSE	108	296000	9.	2916000	10.	460000	756000
MILTON	0	0	0.	2262000	0.	0	0
NAHANT	0	0	0.	407000	0.	0	0
NEEDHAM	25	70000	2.	3219000	2.	0	70000
NEWTON	252	689000	8.	11597000	6.	230000	919000
NORWOOD	312	853000	27.	5132000	17.	3000	855000
PEABODY	461	1262000	25.	6245000	20.	3055000	4317000
QUINCY	485	1326000	15.	10497000	13.	0	1326000
REVERE	72	199000	5.	3533000	6.	0	199000
SAUGUS	0	0	0.	2829000	0.	0	0
SOMERVILLE	350	958000	11.	11004000	9.	0	958000
STONEHAM	318	870000	41.	3337000	26.	100000	970000
SWAMPSCOTT	0	0	0.	1513000	0.	4000	4000
WAKEFIELD	355	970000	38.	3514000	28.	144000	1114000
WALTHAM	1461	3992000	64.	11038000	36.	0	3992000
WATERTOWN	180	493000	13.	4542000	11.	0	493000
WESTON	0	0	0.	1085000	0.	0	0
WINCHESTER	0	0	0.	1995000	0.	890000	890000
WINTHROP	20	55000	3.	1830000	3.	0	55000
WOBURN	84	230000	6.	4763000	5.	4146000	4376000
TOTALS	11983	32741000	17.	312878000	10.	180978000	213719000
NON-MEMBER							
CHICOPEE	1555	4250000	63.	12607000	34.	2170000	6420000
CLINTON	159	435000	32.	3161000	14.	653000	1088000
FRAMINGHAM	489	1338000	20.	7664000	17.	0	1338000
LEOMINSTER	1511	4131000	122.	8121000	51.	1650000	5781000
MARLBOROUGH	154	422000	14.	3365000	13.	0	422000
NORTHBOROUGH	10	28000	3.	616000	5.	0	28000
SOUTHBOROUGH	12	35000	6.	402000	9.	0	35000
S.HADLEY FD1	189	517000	42.	1603000	32.	1000000	1517000
WILBRAHAM	53	146000	11.	792000	18.	0	146000
WORCESTER	22[illegible]3	6020000	34.	25526000	24.	36002000	42022000
TOTALS	6339	17321000	40.	63858000	27.	41475000	58796000
Totals for Study Area	18322	50062000	21	376736000	13	222453000	272515000

Source: MDC Water Usage Study, 1975.

Table 7-2: Major Water-Using Industries in the Study Area

		Water Usage		
Name of User	Community	MDC Plus Community-Owned Supplies (gal/yr)	Estimated Self-Supplied* (gal/yr)	Total (gal/yr)
--	Arlington	0	0	0
Cambridge Plating Co.	Belmont	38,508,000	0	38,508,00
Revere Sugar Refinery	Boston	207,570,000	5,124,000,000 [1]	5,331,570,00
Shrafts Candy	Boston	0	161,040,000 [1]	161,040,00
Proctor & Gamble	Boston	0	695,400,000 [1]	695,400,00
Great A & P Tea Co.	Boston	0	395,280,000 [4]	395,280,00
Boston Naval Shipyard	Boston	0	4,465,200,000 [1]	4,465,200,00
Bethlehem Steel	Boston	28,012,000	347,700,000 [4]	375,712,00
Gillette Co.	Boston	502,843,000	9,259,800,000 [4]	9,462,643,00
L. E. Mason Co.	Boston	0	36,600,000 [1]	36,600,00
Am. Sugar Co.	Boston	227,466,000	2,547,360,000 [4]	2,774,826,00
Diamond Int. Corp.	Boston	59,092,000	732,000,000 [4]	791,092,00
Folding Box Corp.	Boston	0	91,500,000 [1]	91,500,00
Blakes Food Land	Boston	0	8,052,000 [1]	8,052,00
Steadfant Rubber	Boston	0	13,176,000 [1]	13,176,00
Food Products	Boston	0	31,476,000 [1]	31,476,00
Boston Edison	Boston	1,016,359,000	0	1,016,359,00
Stop & Shop Inc.	Boston	65,449,000	0	65,449,00
Boston Sausage	Boston	59,136,000	0	59,136,00
N.E. Tel & Tel Co.	Boston	70,873,000	0	70,873,00
Tonald S. Simons	Boston	126,711,000	0	126,711,00
G. J. Shepard Co.	Boston	41,820,000	0	41,820,00
H.P. Hood & Son	Boston	115,536,000	0	115,536,00
Tarner Ctre. Sys. Inc.	Boston	30,892,000	0	30,892,00
The Hearst Corp.	Boston	26,344,000	0	26,344,00
Hosp. Laundry Assoc.	Boston	79,534,000	0	79,534,00
Morgan Laundry Serv.	Boston	40,893,000	0	40,893,00
Mr. Boston Distiller	Boston	42,628,000	0	42,628,00
Clayton Laundry Co.	Boston	17,376,000	0	17,376,00
Pier 4 Inc.	Boston	29,920,000	0	29,920,00
N.E. Seafood Co.	Boston	38,088,000	0	38,088,00
Penn Central	Boston	64,298,000	0	64,298,00
Craw Coat & Apron	Boston	22,724,000	0	22,724,00
Armour Meats	Boston	49,929,000	0	49,929,00
Columbia Packing Corp.	Boston	44,932,000	0	44,932,00
N. A. Packing Co.	Boston	17,518,000	0	17,518,00
Boston Food Mkt. Corp.	Boston	12,065,000	0	12,962,00
Mass Food Terminal	Boston	15,962,000	0	15,962,0
N. E. Prov Co.	Boston	81,636,000	0	81,636,0
Globe Newspaper	Boston	99,124,000	0	99,124,00
Standard Uniform Co.	Boston	13,621,000	0	13,621,0
Boston Ins. Wire	Boston	18,191,000	0	18,191,
Am. Ice Co.	Boston	23,352,000	0	23,352,
Met. Bottling Co.	Boston	23,808,000	0	23,808,
A-Chalmers Mfg. Co.	Boston	37,826,000	0	37,826,0
B. F. Sturevant Div.	Boston	25,058,000	0	25,058,00

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. Health cross-connection file; [3]supplied by industry; [4]Metcalf & Eddy Industrial ... Survey for E. Mass. Metropolitan Area.

Table 7-2 (Cont'd.): Major Water-Using Industries in the Study Area

Name of User	Community	Water Usage: MDC Plus Community-Owned Supplies (gal/yr)	Water Usage: Estimated Self-Supplied* (gal/yr)	Water Usage: Total (gal/yr)
Still & Sterilizer Co.	Boston	13,591,000	0	13,591,000
Honeywell Inc.	Boston	160,498,000	0	160,498,000
Dy-Dee Service Inc.	Brookline	29,148,000		29,148,000
Dewey & Almy Ch. Co.	Cambridge	79,601,000	142,740,000[4]	222,341,000
Cambridge Electric	Cambridge	0	32,896,080,000[1]	32,896,080,000
Am. Biltrite Rubber	Cambridge	0	347,700,000[4]	347,700,000
Boston Ind. Prod.	Cambridge	0	1,002,840,000[4]	1,002,840,000
Polaroid	Cambridge	371,661,000	0	371,661,000
New England Confec. Co	Cambridge	34,698,000	0	34,698,000
National Biscuit Co.	Cambridge	40,288,000	0	40,288,000
United Carr Fastener	Cambridge	290,615,000	0	290,615,000
Gen. Latex Chemical Co	Cambridge	24,951,000	0	24,951,000
Cabot, Cabot & Forbes Co.	Cambridge	111,872,000	0	111,872,000
Boston Woven Hose & Rubber Co.	Cambridge	35,550,000	0	35,550,000
F. W. Woolworth	Cambridge	12,594,000	0	12,594,000
Devon Confec.	Cambridge	75,053,000	0	75,053,000
Cambridge Gas & Light	Cambridge	155,382,000	0	155,382,000
Arthur D. Little Co.	Cambridge	44,485,000	0	44,485,000
Consolidated Metal Corp	Cambridge	16,864,000	0	16,864,000
Robert Gair Co.	Cambridge	13,058,000	0	13,058,000
Genoa Packing Co.	Cambridge	13,674,000	0	13,674,000
Plymouth Rubber Co.	Canton	15,241,000	0	15,241,000
Draper Bros.	Canton	0	73,200,000[2]	73,200,000
Cumberland Farms	Canton	51,240,000	0	51,240,000
Mankiewieg	Chelsea	12,102,000	0	12,102,000
Monsanto Ch. Co.	Everett	417,005,000	2,562,000,000[1]	2,979,005,000
Boston Edison	Everett	420,660,000	0	420,660,000
Exxon Co.	Everett	146,158,000	0	146,158,000
Mystic Steamship Co.	Everett	19,900,000	0	19,900,000
General Electric	Everett	193,681,000	0	193,681,000
Atlantic Steel & Trading Co.	Everett	32,909,000	0	32,909,000
Avco Co.	Everett	54,591,000	0	54,591,000
Raytheon	Lexington	25,565,000	0	25,565,000
Itek	Lexington	184,393,000	0	184,393,000
Instrumentation Lab.	Lexington	15,067,000	0	15,067,000
Lex Motor Inn	Lexington	12,011,000	0	12,011,000
--	Lynnfield	0	0	0
Converse Rubber	Malden	73,236,000	0	73,236,000
Mass. Electric	Malden	12,940,000	131,760,000[1]	144,700,000
Friend Bros.	Malden	14,758,000	0	14,758,000

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. Health, cross-connection file; [3]supplied by industry; [4]Metcalf & Eddy Industrial Waste Survey for E. Mass. Metropolitan Area.

Table 7-2 (Cont'd.): Major Water-Using Industries in the Study Area

Name of User	Community	Water Usage: MDC Plus Community-Owned Supplies (gal/yr)	Water Usage: Estimated Self-Supplied* (gal/yr)	Water Usage: Total (gal/yr)
--	Marblehead	0	0	0
Rust Proofing	Medford	12,820,000	0	12,820,000
General Chemical	Medford	18,602,000	0	18,602,000
Mystic Plating	Medford	16,852,000	0	16,852,000
Federal Bond Board	Medford	26,082,000	0	26,082,000
Cain Co.	Medford	19,874,000	0	19,874,000
Container Corp.	Medford	18,595,000	0	18,595,000
Radio Mfg. Co.	Melrose	0	168,360,000[1]	168,360,000
Joseph Sawtell	Melrose	14,286,000	0	14,286,000
Tremont Asphalt	Melrose	76,752,000	0	76,752,000
Bexalar Transitron	Melrose	16,965,000	0	16,965,000
--	Milton	0	0	0
--	Nahant	0	0	0
International Equip.	Needham	12,419,000	0	12,419,000
Sylvania	Needham	13,303,000	0	13,303,000
S. W. Industries	Newton	0	84,180,000[3]	84,180,000
St. Regis Paper	Newton	50,688,000	0	50,688,000
Marriott	Newton	44,820,000	0	44,820,000
Veinite Corp.	Newton	41,901,000	0	41,901,000
Norton Metals	Newton	33,688,000	0	33,688,000
Varian Vacuum	Newton	25,800,000	0	25,800,000
A & P	Newton	16,880,000	0	16,880,000
Dunphy Corp.	Newton	13,548,000	0	13,548,000
Barnell	Newton	12,723,000	0	12,723,000
Honeywell, Inc.	Newton	12,067,000	0	12,067,000
New London Mills	Norwood	35,209,000	0	35,209,000
M. T. Acquiring	Norwood	30,686,000	0	30,686,000
Poloroid Corp.	Norwood	70,379,000	0	70,379,000
Factory Mutual	Norwood	12,721,000	999,000[3]	13,721,000
Brook Molding	Norwood	23,037,000	0	23,037,000
Northrop	Norwood	69,558,000	0	69,558,000
Bird & Son Inc.	Norwood	70,416,000	0	70,416,000
Lawrence Leather Co.	Peabody	95,755,000	125,904,000[3]	221,659,000
Eastman Gelatine Co.	Peabody	16,123,000	974,000,000	990,123,000
Fermon Tanning Co.	Peabody	23,990,000	0	23,990,000
North Shore Shopping Center	Peabody	27,962,000	0	27,962,000
Orgettas Leather Co.	Peabody	50,697,000	0	50,697,000
Remis Industries	Peabody	18,064,000	0	18,064,000
Rex Tanning Corp.	Peabody	13,628,000	16,900,000[3]	30,528,000
Sirois Brothers Inc.	Peabody	17,316,000	0	17,316,000
United Finish Co.	Peabody	47,968,000	0	47,968,000
Victory Tanning Co.	Peabody	26,661,000	1,170,000[3]	27,831,000
Walbar Machine Products Co.	Peabody	19,632,000	0	19,632,000
Webster Industries	Peabody	47,850,000	0	47,850,000

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. [illegible] cross-connection file; [3]supplied by Industry; [4]Metcalf & Eddy Industrial Survey for E. Mass. Metropolitan Area.

Table 7-2 (Cont'd.): Major Water-Using Industries in the Study Area

Name of User	Community	Water Usage: MDC Plus Community-Owned Supplies (gal/yr)	Estimated Self-Supplied* (gal/yr)	Total (gal/yr)
USM Corp.	Peabody	39,009,000	0	39,009,000
Eastern Tanning Co.	Peabody	17,266,000	0	17,266,000
Proctor & Gamble	Quincy	70,396,000	0	70,396,000
General Dynamics Corp.	Quincy	278,368,000	0	278,368,000
Raytheon	Quincy	67,874,000	0	67,874,000
Murray Co.	Quincy	21,291,000	0	21,291,000
Boston Edison Co.	Quincy	25,550,000	0	25,550,000
Old Colony Laundry	Quincy	13,286,000	0	13,286,000
Ogden Suffolk Downs	Revere	17,194,000	0	17,194,000
--	Saugus	0	0	0
Swift & Co.	Somerville	54,087,000	0	54,087,000
M. M. Mades	Somerville	41,843,000	0	41,843,000
Boston & Maine Corp.	Somerville	44,880,000	0	44,880,000
Finast	Somerville	108,721,000	0	108,721,000
H. K. Porter	Somerville	17,226,000	0	17,226,000
Cott Bottling	Somerville	60,131,000	0	60,131,000
Hi-G, Inc.	Somerville	23,576,000	0	23,576,000
Stoneham Laundry	Stoneham	13,643,000	36,600,000[3]	50,243,000
Atlantic Gelatin	Stoneham	290,859,000	1,189,500,000[3]	1,480,359,000
Sunnyhurst Dairy	Stoneham	13,900,000	0	13,900,000
--	Swampscott	0	0	0
Wakefield Bearing	Wakefield	0	52,704,000[3]	52,704,000
Wakefield Eng.	Wakefield	12,611,000	0	12,611,000
Transitron	Wakefield	355,142,000	0	355,142,000
Raytheon	Waltham	553,975,000	0	553,975,000
Polaroid	Waltham	417,244,000	0	417,244,000
Canada Dry	Waltham	86,480,000	0	86,480,000
Gen. Tel. & Tel.	Waltham	77,752,000	0	77,752,000
Standard Thompson	Waltham	76,081,000	0	76,081,000
Hewlett Packard	Waltham	37,941,000	0	37,941,000
Waltham Engineering	Waltham	34,355,000	0	34,355,000
J. L. Thompson Mfg.	Waltham	30,727,000	0	30,727,000
Reeve Corp.	Waltham	26,738,000	0	26,738,000
Printed Circuit	Waltham	23,573,000	0	23,573,000
Witt. Nichols	Waltham	20,899,000	0	20,899,000
Jarrell Ash	Waltham	20,368,000	0	20,368,000
Honeywell	Waltham	17,616,000	0	17,616,000
Donnelly Mfg.	Waltham	21,436,000	0	21,436,000
Infrared Ind.	Waltham	12,095,000	0	12,095,000
George W. Moore, Inc.	Waltham	13,399,000	0	13,399,000
The Barry Corp.	Watertown	29,904,000	0	29,904,000
Unitrode Transitron Products	Watertown	63,700,000	0	63,700,000
Ionics, Inc.	Watertown	13,849,000	0	13,849,000
Haartz-Mason, Inc.	Watertown	23,437,000	0	23,437,000
Bemis Mfg. Assoc.	Watertown	17,950,000	0	17,950,000

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. Health, cross-connection file; [3]supplied by industry; [4]Metcalf & Eddy Industrial Waste Survey for E. Mass. Metropolitan Area.

Table 7-2 (Cont'd.): Major Water-Using Industries in the Study Area

Name of User	Community	Water Usage: MDC Plus Community-Owned Supplies (gal/yr)	Estimated Self-Supplied* (gal/yr)	Total (gal/yr)
Quincy Mkt. Cold Storage & Wholesale	Watertown	15,362,000	0	15,362,000
Wm. Underwood Co.	Watertown	16,269,000	0	16,269,000
--	Weston	0	0	0
J. H. Winn Co.	Winchester	0	325,740,000[1]	325,740,000
Duval Industries	Winthrop	20,173,000	0	20,173,000
Alpha Ind.	Woburn	37,811,000	0	37,811,000
New England Plastics	Woburn	14,668,000	14,668,180[3]	29,336,000
Johnson's Bros. Grnhse.	Woburn	18,086,000	0	18,086,000
Tanners Degreasing	Woburn	13,464,000	60,840,180[3]	74,304,000
J. J. Riley	Woburn	0	90,000,000[3]	90,000,000
NONMEMBERS				
Corenco Corp.	Chicopee	0	225,456,000	225,456,000
Eastern Etching & Mfg.	Chicopee	0	18,300,000	18,300,000
Moore Drop Forging	Chicopee	31,673,000	36,600,000	68,273,000
A. G. Spaulding	Chicopee	447,483,000	0	447,483,000
Industrial Building	Chicopee	82,897,000	0	82,897,000
U.S. Rubber	Chicopee	765,398,000	0	765,398,000
Shine Chicopee Co.	Chicopee	27,745,000	0	27,745,000
Prod. Pattern Fdry.	Chicopee	15,389,000	0	15,389,000
Hampden Brewing Co.	Chicopee	159,837,000	0	159,837,000
Blackstone Mills	Clinton	0	62,220,000[1]	62,220,000
Van Brode Mfg.	Clinton	57,435,000	8,784,000[1]	66,219,000
ITT Supernant Mfg. Co.	Clinton	21,737,000	167,999,856[3]	189,737,000
Marine Plastics	Clinton	67,474,000	0	67,474,000
Phoenix Plastics Co.	Clinton	12,456,000	0	12,456,000
General Motors	Framingham	198,558,000	0	198,558,000
Denison Mfg. Co.	Framingham	205,179,000	0	205,179,000
Sealtest Foods	Framingham	69,494,000	0	69,494,000
Nu-Form Plastics	Leominster	12,021,000	0	12,021,000
Jofal	Leominster	18,331,000	0	18,331,000
Synthetic Materials	Leominster	56,334,000	0	56,334,000
Solor Chemical	Leominster	136,931,000	0	136,931,000
Norman F. Basque	Leominster	14,226,000	0	14,226,000
Borden	Leominster	242,903,000	0	242,903,000
Du Pont de Nemours	Leominster	24,390,000	84,326,400[1]	108,717,000
Comm. Plastics	Leominster	51,660,000	0	51,660,000
Mohawk Wire & Cable	Leominster	19,651,000	0	19,651,000
Castle Plastics	Leominster	20,475,000	0	20,475,000
Seppala & .ho Constr.	Leominster	19,818,000	0	19,818,000
Foster Grant	Leominster	762,810,000	457,500,000[3]	1,220,310,000
Borenco Dev.	Leominster	33,068,000	0	33,068,000
Lendeco Inc.	Leominster	13,064,000	0	13,064,000
Kemark Realty	Leominster	24,488,000	0	24,488,000
Bay State Plastics	Leominster	12,929,000	0	12,929,000
Clear Shield Plastics	Leominster	13,746,000	366,000,000[3]	379,746,000
Kell Plastics Corp.	Leominster	25,062,000	0	25,062,000

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. Health cross-connection file; [3]supplied by industry; [4]Metcalf & Eddy Industrial Wa Survey for E. Mass. Metropolitan Area.

Table 7-2 (Cont'd.): Major Water-Using Industries in the Study Area

Name of User	Community	Water Usage: MDC Plus Community-Owned Supplies (gal/yr)	Estimated Self-Supplied* (gal/yr)	Total (gal/yr)
Union Products	Leominster	0	18,446,000 [3]	18,446,000
J. P. Miller	Leominster	0	32,500,000 [4]	32,500,000
Zar-X	Marlborough	34,469,000	0	34,469,000
I-Likon Corp.	Marlborough	15,000,000	0	15,000,000
Stop & Shop	Marlborough	104,993,000	0	104,993,000
Ernest F. Lawrence	Nthborough	10,243,000	0	10,243,000
L. B. Darling Inc.	Southbrgh.	12,835,000	0	12,835,000
Texon, Inc.	So. Hadley	39,586,000	366,000,000 [3]	405,586,000
Scott Graphics, Inc.	So. Hadley	92,367,000	0	92,367,000
Nonotuck Mfg. Co.	So. Hadley	57,774,000	0	57,774,000
State Line Potato Chip	Wilbraham	37,767,000	0	37,767,000
Friendly Ice Cream	Wilbraham	15,836,000	0	15,836,000
Am. Steel & Wire	Worcester	0	450,180,000 [1]	450,180,000
Mass. Electric	Worcester	24,050,000	12,700,200,000 [1]	12,724,250,000
Norton	Worcester	401,987,000	264,471,000 [3]	666,459,000
Hearld Machine Co.	Worcester	27,125,000	0	27,125,000
Worcester Pressed Steel Co.	Worcester	39,966,000	0	39,966,000
Reed & Prince Mfg. Co.	Worcester	128,740,000	0	128,740,000
Warren & Swassey Co.	Worcester	28,421,000	0	28,421,000
Polar Corp.	Worcester	45,567,000	0	45,567,000
Presmet Corp.	Worcester	64,961,000	0	64,961,000
Coca Cola Bottling	Worcester	38,279,000	0	38,279,000
N. E. Metallurgical Co.	Worcester	18,855,000	0	18,855,000
Astra Pharmaceutical Co.	Worcester	42,581,000	0	42,581,000
Plaza Center	Worcester	21,021,000	0	21,021,000
U. S. Envelope Co.	Worcester	22,199,000	0	22,199,000
Johnson's Steel & Wire	Worcester	105,829,000	0	105,829,000
Millbrook Inc.	Worcester	17,106,000	0	17,106,000
Sprague Electric Co.	Worcester	70,406,000	0	70,406,000
U. S. Steel Co.	Worcester	106,169,000	0	106,169,000
Modern Mfg. Co.	Worcester	15,953,000	0	15,953,000
Edward Garenpy, Inc.	Worcester	13,342,000	0	13,342,000
Worcester Cold Storage	Worcester	32,273,000	0	32,273,000
Worcester Molded Plastic	Worcester	34,040,000	0	34,040,000
Eagle Electro Plating	Worcester	53,741,000	0	53,741,000
Dapel Plastic	Worcester	12,178,000	0	12,178,000
Barnell Elec. Corp.	Worcester	13,084,000	0	13,084,000
Wyman Gordon Co.	Worcester	166,647,000	0	166,647,000
Standard Foundry	Worcester	22,570,000	0	22,570,000
Thompson Stall Co.	Worcester	79,952,000	0	79,952,000
Wright Steel Co.	Worcester	22,730,000	0	22,730,000
N. E. Plating Co.	Worcester	29,196,000	0	29,196,000

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. Health, cross-connection file; [3]supplied by industry; [4]Metcalf & Eddy Industrial Waste Survey for E. Mass. Metropolitan Area.

Table 7-2 (Cont'd.): Major Water-Using Industries in the Study Area

		Water Usage		
Name of User	Community	MDC Plus Community-Owned Supplies (gal/yr)	Estimated Self-Supplied* (gal/yr)	Total (gal/yr)
Androck, Inc.	Worcester	42,824,000	0	42,824,0
Worc. Telegram Pub. Co.	Worcester	34,390,000	0	34,390,00
New Method Plating	Worcester	25,502,000	0	25,502,00
Crompton & Knowles Loom Works	Worcester	61,593,000	0	61,593,00
Table Talk Pastry Co.	Worcester	40,810,000	0	40,810,00
Parker Mfg. Co.	Worcester	38,099,000	0	38,099,00
Prouf, Inc.	Worcester	73,885,000	0	73,885,00

*Data sources are as follows: [1]EPA permit files; [2]Mass. Dept. of Pub. Heal cross-connection file; [3]supplied by industry; [4]Metcalf & Eddy Industrial W Survey for E. Mass. Metropolitan Area.

Appendix I-9

FUTURE SUPPLY NEEDS IN MILLION GALLONS PER DAY WITHOUT DEMAND MODIFICATION

Industrial Consumption

	1970	1990	2020
Essex County			
Beverly	0.614	0.997	1.453
Danvers/Middleton	0.690	1.121	1.633
Gloucester	1.557	2.529	3.684
Lynn	4.520	7.343	10.696
Salem	2.600	4.224	6.153
County Totals	9.981	16.214	23.619
Middlesex County			
Reading	0.207	0.336	0.490
Norfolk County			
Braintree	0.800	1.300	1.893
Dedham/ Westwood	0.154	0.250	0.364
Foxborough	0.456	0.741	1.079
Franklin	0.261	0.424	0.618
Millis	0.126	0.205	0.298
Plainville	0.321	0.521	0.760
Stoughton	0.042	0.068	0.099
Walpole	0.530	0.861	1.254
Wellesley	0.160	0.260	0.379
County Totals	2.850	4.630	6.744
Plymouth County			
Brockton	1.428	2.320	3.379
Hingham	0.156	0.253	0.369
Plymouth	0.100	0.162	0.237
County Totals	1.684	2.735	3.985
Bristol County			
Attleboro	4.000	6.498	9.466
Dighton	0.100	0.162	0.237
Easton	0.040	0.065	0.095
Fall River	3.270	5.312	7.738
Mansfield	0.850	1.381	2.011
New Bedford	12.330	20.030	29.177
Somerset	0.258	0.419	0.610
Taunton	2.394	3.889	5.665
County Totals	23.242	37.756	54.999
Area Totals	37.964	61.671	89.837

Source: Northeastern United States Water Supply Study (NEWS), U.S. Army Corps of Engineers, 1974.

Appendix II

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NCAC Comments: DEMAND/USE

1) Q: The demand for water expressed by Connecticut communities must be included in t assessment of data. East Hartford should be considered along with Hartford, Middletown, and Essex.

A: A meeting was held between WFEM and the staff of the Natural Resources Center c the Connecticut Department of Environmental Protection at their offices on June 26, 1980. At this meeting the inclusion of Connecticut's water demand related the alternatives being considered for the Connecticut River was discussed. It was agreed, based on their existing information and ongoing studies, that the future demand for water among communities within the watershed would be adequately covered by assessing the demand for water of the greater Hartford ar and Middletown. East Hartford is included under the service area of the Hartfc MDC and will be part of the metropolitan area analysis, while Essex and other secondary growth communities within the watershed were excluded because they we deemed to be of limited usefulness to the study as their future demand was anticipated to be small.

2) Q: Page 1 - A statement of purpose explaining what kinds of water use will be deal with in the memo would be helpful at the top of page one.

A: See revision made in the text.

3) Q: Page 2 - Middle paragraph - Some RPA's (i.e., LPVRPC) developed population projections in 1977, rather than "in the early 1970's".

A: While it is true that population projections developed by LPVRPC and other RPA' were made after the work done by OSP, these later figures are still based on th earlier methodology and revised only insofar as general growth indicators and area development information allowed. These figures were still based on 1970 census data and they still were constrained by regional total limits. They appear to have no greater accuracy or significant population variation than earlier projections.

In the absence of 1980 census data, the most recent statewide population figure will be used to develop the preliminary, "first-cut" demand estimates. These figures most likely will be the ones developed for regional 208 Water Quality studies by the RPA's and will include the 1977 figures of LPVRPC. A comparison will be made, however, between more recent figures and those remaining from OSP in order to be sure that the updates and revision that were made are consistent with an accepted methodology and that the updates using 1980 census figures. wh these become available, are made to the most acceptable base figures.

4) Q: Page 3 - figure 1 - The figure caption needs a clearer explanation. The term "multi-family" should be defined (does this category include garden apartments? or are garden apartments included in the commercial category?) Why is the focu on "indoor" water consumation? Shouldn't consideration also be given to water used for lawn-watering? car washing? and swimming pool filling?

A: Table 1 portrays a list of the components of consumption that are "potentially" those to be studied. The uncertainty lies in the degree to which these categories can be disaggregated from data available from state and local sources. Under the category of multi-family use the breakdown is only intended

to differentiate between this category and single-family use. While it was originally conceived to include several categories such as garden apartments or low-rise/high-rise apartments, it was determined that such delineation for multi-family is not possible given the state of the data. Therefore, no further breakdowns are anticipated under this general category of higher density residential consumption.

The "indoor" label alongside the multi-family category was intended to show that for most multi-family dwellings, located in more urbanized areas, outdoor usage is minimal in comparison to single-family usage that does include lawn sprinkling, car washing, etc. Where there is significant outdoor usage associated with a multi-family complex, it is likely to be for the entire complex, like filling a pool or watering shrubs, rather than on a per household basis. Where possible significant outdoor usage of this sort will be distributed among all households in a multi-family complex.

5) Q: Page 4 - last paragraph - Chief elected officials of communities will get preliminary figures from the Bureau of the Census in late June or early July. Individual NCAC members may be helpful in obtaining this information for WFEM.

A: This will be pursued.

6) Q: Page 5 - paragraph 2 - More explanation is needed for the proposed "range of actual consumption trends" and the "correction factor" to be applied.

A: See revisions made in text. What is intended here is to compare recent actual consumption with earlier projections that were made in order to revise per capita consumption for use in the preliminary "first-cut" demand estimates.

7) Q: Page 5 - paragraph 4 - Seasonal variations in current consumption should be determined.

A: Agreed. This will be done by comparing peak seasonal usage for winter months and summer months for domestic categories associated with outdoor usage.

8) Q: Page 5 - paragraph 5 - Straight line projections can be misleading. The last sentence is not clear -- is the intent that "straight line projections" will include "input from local and regional planners?

A: Straight line projections are intended to be used for the twenty year increment beyond 2000. Existing projections are made to the year 2000 so that the additional period will be straight-lined since no more accurate information, for our purposes, is available that would allow a better projection to 2020. For the preliminary estimates no revisions to population figures are anticipated. Once the 1980 census becomes available, however, more detailed analysis including input from local and regional planning agencies will be carried out. This more detailed analysis will be utilized for the refined demand estimates to be done in the Phase II analysis.

9) Q: Page 6 - figure 2 - The figure caption needs a clearer explanation.

A: See revisions made in text.

10) Q: Page 8 - paragraph 1 - To what does the * refer?

A: See revisions made in text.

11) Q: Page 8 - paragraph 4 - The first sentence is not clear. Documentation for the studies mentioned for California would be useful. Where in the "conservation alternative memo" is "this issue addressed in greater detail"?

A: See revisions in text.

12) Q: Page 8 - paragraph 5 - The statement "that domestic water requires a greater more costly degree of pre-treatment than most other water use" should be qualified.

A: See revisions in text.

13) Q: Page 9 - paragraph 4 - To what does the * refer to?

A: See revisions in text.

14) Q: Page 9 - paragraph 4 - George Boyle of the Hampshire County Planning Department believes that the reasons for variability in water consumption for communities in western Massachusetts are fairly obvious. Will the analysis of variability include eastern as well as western Massachusetts?

A: Estimates of water consumption and development of use factors will be based on user profiles for communities in both the eastern and western parts of the state.

15) Q: Page 9 - paragraph 5 - References should be cited for outdoor usage in western United States.

A: See revisions in text.

16) Q: Page 10 - paragraph 2 - References would be helpful for "studies in California".

A: See revisions in text.

17) Q: Page 10 - paragraph 2 - George Boyle, Director of the Hampshire County Planning Department, favors the use of per-capita figures in projecting demand. He points out that there are more households now than there were in the 1950's or 60's, but indicates that household size is smaller now than it used to be.

A: This question of household versus per-capita as the unit of measure for projecting future demand is an important one insofar as it addresses a point in the methodology of this study. Mr. Boyle's view is one which many resource planners share and which merits careful consideration. As presented in our report and memo, it is our hypothesis that for the purposes we have set out, a household is the more significant water consumption unit. Since this is a relatively new issue there are no definitive studies on the subject, but the literature seems to suggest some advantages to a household measure over the traditional per-capita unit. We intend, of course, to consider household size as a check on this measure in order to reflect whatever changes do occur in usage between large and small sized households.

As was pointed out in the technical memo, it is precisely because of the variations among users and between categories of users that the analysis of current consumption will be made and a profile of users drawn. It is hoped that usage factors that reflect these variations in use will result and can be incorporated to the study.

The trend of increasing numbers of households coupled with decreasing per-capita size and increasing domestic water consumption since the 1950's suggests that our hypothesis may be a reasonable one. Increased use of water intensive appliances, the greater numbers of homeowners, conversions of apartments to condominiums, and the fewer numbers of people making up a family indicate that a household consumption measure would be more reflective of these recent trends than would a per-capita measure. Since at this stage in the analysis we can only suggest that the data will support this hypothesis, we will be testing it further as the analysis progresses and if necessary will make adjustments to reflect the data available.

18) Q: Page 11 - Massachusetts Water Resources Commission - The Commission began to require communities to report water plans in 1979.

A: See revisions in text.

19) Q: Page 11 - Regional Planning Agencies - Will reports from RPA's in Connecticut (i.e., Windham Regional Planning Commission) be included? What references is meant by "the LPVRPC has some information on per-capita domestic consumption...to the year 2020"?

A: Connecticut data is being developed by the State Department of Environmental Protection (see response to #1). Follow up analysis will be carried out if deemed necessary by DEP's planners to be consistent with the scope of this study for Massachusetts.

The reference to LPVRPC refers to thir recently published 208 Water Quality report which affords some secondary data useful to the analysis. See revisions in text.

20) Q: Page 12 - Individual Communities - NCAC would like to know if any communities in the Connecitct River Valley "have organized their water use data and developed information systems in some cases linked to local water department billings on a computer system"?

A: At this stage of the analysis no systematic listing of how the data on water consumption is organized by each community is available. Those communities known to be on a computer billing system are predominatly in the eastern part of the state and generally those with large municipal systems. This is particulary true for those cities and towns on the MDC system. Some local water departments in the Connecticut Valley may likewise now be on or planning to go onto a computer system which may aid in developing the consumption profiles. The survey of local water departments will include communities in the westeran and central parts of the state as well as the eastern communities to reflect the range of data, pricing levels, and organization practices of local water departments.

21) Q: Page 12 - New England Regional and National - The Governors of both New Hampshire and Vermont expressed interest in the direction of this study in Spring of 1979 (see enclosed letters).

A: The comments of all potentially affected states - N.H., VT. and CT. -- will be considered in the formulation of our study approach. In the case of the flood skimming alternatives, specific attention will be paid to both downstream and upstream users in assessing future demand and potential impacts.

22) Q: Page 12 - Data Gaps and Deficiencies - There also appears to be a lack of information on the type of industrial use (boilers, in processes, etc.).

A: Industrial use is addressed in a separate section of this memo. As is noted in that section, it is true that little current data exists or is available on industrial usage. We have proposed an indepth survey to address this gap in the data.

23) Q: Page 13 - Outside Use - Will any consideration be given to the use of drought-resistent plants in "public open space and parkland planning"?

A: Use of such plants may be part of a long range public education program under a conservation strategy, however, in terms of estimating local or private use of such plant materials for purposes of making demand estimates, no data exists which can be used to make these projections. No estimates will be made of their use.

24) Q: Page 14 - figure 3 - This "Domestic Consumption Profile" is not clear; it needs detailed explanation.

A: This figure has been deleted since the information contained in it is addressed elsewhere in the study.

25) Q: Page 15 - paragraph 1 - Will data collected using "case studies and representative samples" really be adequate?

A: Based on the methodology being employed, and given the limitaions in the data and uncertainties that exist with any projections to the year 2020, it is anticipated that the information being developed on consumption by categories and usage factors will be both adequate and of greater usefulness than relying on traditional per-capita methods alone. As pointed out in the report, a per-capita estimate will be made as a preliminary measure, with a more detailed refinement from the analysis of usage and updated population data added as a second-cut analysis.

Using case studies and samples to develop consumption factors is more than adequate insofar as this study design provides because the data has been lacking up to now on consumption and because previous studies have generalized consumption into a common per-capita factor. While accurate and consistent data for all towns would be ideal, that is not available and, therefore, the proposed method expects to provide a consistent and reasonable way to make estimates of future demand. Since these are estimates in any case and not actual consumption in the year 2020, the method is adequate as defined. The sample and case study method will be designed to reflect the range of community types and user characteristics found in the regions under study.

26) Q: Page 15 - Collection of Data on Issues #1 - DEQE (which used to be the Massachusetts Department of Public Health) has data which go back to the 1950's. Data may also be available from the Hartford MDC and from the Connecticut State OPM.

A: The data does go back to earlier years for both DEQE and MDC consumption; WRC reports have only recent annual data. The problem, however, lies in the

consistency and coverage of that historical (and recent) data. It has only been in the last few years, since 1978, that data by user categories for communities across the state has been recorded so that to assess the broad study area(s) being considered only this most recent data was available.

Data for Connecticut is being developed according to the Department of Environmental Protection's quidelines and methodology. (see response to #1.)

27) Q: Page 15 - Collection of Data on Issues #3 - NCAC suggests that WFEM use data from a quarter of the year for seasonal changes, since some heavy water use occurs in April and May. Will data be pulled from an "average" year, or will the driest, wettiest, hottest, and coldest year on record be included?

A: Data will be compiled from a sample of communities in order to profile a representative range of seasonal usage. In most instances it will be the billing cycle of the local water departments--i.e., quarterly, biannual, annual--that will determine the summer and winter months used for comparison. All reasonable attempts will be made, working with the local water superintendents, to reflect average recent consumption trends. No analysis of extreme weather conditions will be made.

28) Q: Page 16 - first paragraph - In dealing with multi-family residences, will consumption in elderly and non-elderly residences be separated? Studies show that elderly people use less water.

A: Elderly residences will not be disaggregated in our breakdowns since it cannot be assumed that elderly people are concentrated in any one location or residential type, and even among a category of use such as elderly actual usage can vary. Elderly usage, along with teenage use or other age levels, will be aggregated into an overall usage factor for the two categories of residential use being compiled. To the extent that data on elderly housing or nursing homes is available under those institutional category of usage, some figures on this usage may be derived if significant variation of consumption is indicated.

29) Q: Page 17 - Apply Demand Management/Conservation Factors - Where will "contamination of supplies" be covered in the study? Any consideration of contamination should include both organic and inorganic contaminents..

A: Contamination of local water supplies will be addressed in terms of assessing possible future users of the MDC system. Both presently contaminated local supplies and possible future contaminated supplies will be considered. The consideration of contaminants is one being addressed also by New England Research in terms of water quality issues and as such is not addressed in this section of the report.

30) Q: Page 17 - Industrial Demand/Use, Introduction - "Exhibit 2" should be changed to "Figure 2".

A: See revisions in text.

31) Q: Page 18 - first paragraph - Industrial use may be related to the type of industry under investigation and their volume of sales.

A: That is correct, in fact, several other categories of industry-related data, like employment and production levels also would apply and will be analyzed.

32) Q: Page 19 - figure 4 - What do the two columns of numbers represent? mgd? bgy? Cf

A: The figures are mgd. See revisions to text.

33) Q: Page 20 - figure 5 - What does "SIC" stand for? What is the "CoofM"? What is meant by "gal/emp-day"? What is the source of this table?

A: SIC refers to Standard Industrial Classification, an organization of industry by major categories according to types of products manufactured, made by the US Department of Commerce. CofM refers to the Census of Manufacturers a periodic survey of industry made by the Department of Commerce.

Gal/emp-day refers to a calculation based on the data contained in the first fou columns whereby the gallons consumption is divided by number of employees and daily use to create the measure shown as "gallons per employee per day".

34) Q: Page 21 - figure 6 - What was the source of this table for the Massachusetts Water Supply Study?

A: This was based on in-house background data developed for the Water Supply Study by WFEM.

35) Q: Page 24 - figure 8 - How are the categories in the left-hand column defined (i.e., "individual additional community that may get MDC water" or groups of impacted communities"?) The way these categories are defined should be discusse by WFEM, MDC, and NCAC.

A: The categories of user and potential user communities that are suggested in the matrix correspond to the series of maps developed for the public presentations, and the questions of possible study area communities to be identified. The specific communities under the headings of "Additional Communities" and "Impacte Communities" are being developed and will be discussed further when the information has been analyzed.

36) Q: Page 25 - SIC Code - Some explanation as to what SIC stands for would be helpful

A: See revisions to text; also see response to question #33.

37) Q: Page 25 - Output - The volume of sale should be examined.

A: While sales volume can be a useful statistic in terms of understanding one aspec of industry performance relative to others, it is not reflective of industry production and water use. Because sales are often tied to specific marketing an financial requirements and since sales volume can shift significantly based on inflation alone, it is not an accurate measure of a company's production or process functions. For this reason it is not one of the parameters to be analyzed.

38) Q: Page 26 - figure 9 - What is the "background paper for State Water Policy Study"

A: See response to #34.

39) Q: Page 28 - Data Review and Evaluation - NCAC suggests that a big chart be made of all the kinds of information available, then determine where the most data are available (on the federal, state, or local level).

A: A chart showing the kinds of information available has not been developed for public presentation purposes because such information does not lend itself to a graphic format. Making a chart which identifies the wide range of sources, materials, publications and reports identified would prove to be difficult and perhaps less useful than the methods employed. This information has been compiled in the working notes and files of the project and it is being examined by each of the consultants according to their specialties.. Presentation of this information was made in the technical memos, with explanatory comments, as well as in the bibliographies to the memos, and discussions of the sources was a focus for the public meetings and project presentations.

40) Q: Page 28 - Historical Employment Data - The Division of Employment Security only records "covered people". There may be a lot of people not covered in the commercial sector. In Hampshire County historical data are readily available on a five year basis at the county level, rather than on an annual basis.

A: This information will be factored into the analysis.

41) Q: Page 33 - References - This list must be better integrated into the body of the paper. As it stands now, the reader has no idea what page any of these studies correspond to.

A: See revision in text.

42) Q: Page A2 - Lexington - The 25.6 mg/yr figure for Raytheon is out-of-date; and MDC sewer study has more recent data for Raytheon.

A: This data will be updated where more recent information is available.

43) Q: Page A24 is blank - please send NCAC another copy.

A: This has been done.

OTHER COMMENTS: Demand/Use

1) Q: Are we considering the local census data available from the Secretary of State's office?

A: WFEM has talked with staff at the state census office and are aware of the local census data that is available from them. This data is available for all cities and towns in the Commonwealth on an annual basis. There is also a state census that is carried out in mid-decade between the years of the federal census.

The local census by cities and towns is really a count of residents that includes only those people 17 years and older. It is not conducted with any statewide consistency nor are the figures uniformly accurate for cities and towns since it is the individual communities that take the counts. While of interest in reflecting local counts during those years when no official census was made, these numbers are not useful for the purposes required in the study. Likewise, the state census provides some information between census years, but not of a consistency or accuracy applicable to the study. Because of the expected availability of 1980 Federal census data that source will be emphazised.

2) Q: Is the reporting of consumption figures by local water departments being made accurately or are the estimates that are made, in some cases, exaggerating actual water use?

A: While some local water deptartment estimates may be either too high or too low, it is felt that many local water superintendents have sufficient experience and knowledge of their systems to estimate consumption reasonably and that is acceptable to the study.

As a further check of the accuracy of local consumption figures, the interviews to be conducted in a sample of communities will address the accuracy of the consumption figures.

3) Q: Question of possible built in bias in making demand estimates towards receiver communities at expense of donor communities.

A: The assessment of population growth uses federal and state projections which are based on a variety of economic, demographic and migration factors that go beyond merely the availability of water. The growth in one region or another, or the lack of growth does not depend solely on the availability of water. While there is no conclusive data to show that one precedes the other, rapid growth and development can occur in areas with shortages of water while areas with available supplies can experience slow growth based on other economic forces.

The trends and factors which influence growth are too complex to assume a single causal relationship exists. Therefore, basing our demand assessment on population projections should not be inconsistent from one region to another or from one part of the state to another. It is anticipated that the assistance to be provided by the RPA's will enable a better focus and sensitivity to trends in the various parts of the state, and preclude any bias in assessments.

As far as data on the western part of the state is concerned, we expect to include adequate coverage of Connecticut Valley and Central Massachusetts communities as well as eastern cities and towns in our sample of towns for the demand projections.

4 Q: How will the issue of local/regional water supplies be addressed?

A: Where the possibility exists for adequate local supplies serving a regional demand, this will be factored into the analysis by examining the range of possible future user alignment for the MDC system. Any changes in user alignment from present arrangements will be factored into the available safe yield calculations.

5 Q: How will the recent trends in industrial water use and conservation measures be included in the analysis?

A: The survey of major industrial users will assist us in determining the extent of reductions and conservation measures among current industry and the degree of further reductions possible. This will help to determine the potential future reductions across industrial groupings based on the use profile analysis to be developed.

Q: How will the study determine whether the existing supplies can accomodate future demand, given current system proposals and conservation measures, without requiring further engineered supply alternatives.?

A: Based on the population growth and demand projections made and the safe yield calculations of the existing system, the assessment will be made of any potential short fall in the system. Conservation and demand management resources will be applied to these estimates, however, in some cases these factors will provide only possible measures of supply rather than guaranteed ones, so that the potential savings from conservation and demand management cannot be assumed as a sole basis for meeting estimated future demand.

Technical Memorandum
EVALUATION OF INFORMATION TO ASSESS
SAFE YIELD/STREAMFLOW

Prepared by Arthur D. Little Inc.
July 1980

1.0 SUMMARY

Analyses to determine the safe yield of alternative plans to augment the water supply of the MDC system can be performed by use of a simulation model executed by a computer program. The input required for the program are the data required for safe yield analysis. The program can also include routines to analyze changes in streamflows as a consequence of implementation of various alternatives.

The major issues associated with the safe yield and streamflow analysis are discussed under three headings: (1) the concept of safe yield and the variables that can influence the analysis of a complex water supply system; (2) methods of analysis, including both simulation and non-simulation techniques; and (3) streamflow (discharge) records and their transformations.

The necessary data are then identified under six categories: (1) streamflow, (2) other hydrologic, (3) system facilities, (4) operating rules and institutional constraints, (5) withdrawal functions, and (6) stage-discharge relationships. The existing information within these categories is then described and evaluated. Finally, a recommended approach for collecting the baseline data and preparing them for use in the analysis is given.

In general, most of the data that will be required are available and can be transformed for use as input to the computer program. Some data gaps exist, but it is expected that they can be filled using existing information or by program algorithms. The program and its data base will be designed so that they can be modified and updated in the future, thereby providing a long-term tool for analysis of the MDC supply system.

2.0 INTRODUCTION

The current MDC system is supplied with water from three regular sources. The safe yield of these sources have been estimated to be:

Source	Safe Yield (mgd)
Quabbin Reservoir	155
Ware River	40
Wachusett Reservoir	105
Total	300

The demand for water from the MDC system already exceeds the safe yield. Alternative methods of supply augmentation or conversely, decrease in demand, have been proposed.

The safe yield values given for these alternatives, described below, are intended to only give approximate magnitudes. Some values are based on detailed studies and good data, while others are only estimates using limited data. Furthermore, the cost of providing the additional yields vary considerably, and full development of each alternative may not be economically feasible.

(1) Upper Sudbury Watershed. This plan includes adding water treatment facilities to the Sudbury Reservoir system, which is currently used primarily in a reserve capacity. The safe yield increase has been estimated to be approximately 20 mgd.

(2) Merrimack River. Water would be withdrawn from the Merrimack River, either during heavy flow periods only or on a year-round basis. Depending on the method, the increase in safe yield could range from 35 to 550 mgd.

(3) Connecticut River Tributaries. The principal action under this proposal would transfer water from the upper part of the Millers River watershed to the MDC system. The increase in safe yield has been estimated at from 48 to 76 mgd depending on which of three alternative plans is adopted.

(4) Groundwater and surface water in Eastern Massachusetts. This plan would tap local water supplies, including Plymouth County aquifers. Safe yields could vary considerably depending on the extent of development.

(5) Water conservation, including repairs to distribution system. This alternative would serve to decrease demand rather than to increase the supply. Various estimates have been made on the extent to which water could be "saved".

(6) Desalination. This alternative would transform sea water into potable water along coastal areas. The safe yield is essentially infinite, but cost, particularly for energy required, represents the major constraint.

(7) Quabbin Watershed Management. The intent here would be to increase the runoff to Quabbin Reservoir by reducing evapotranspiration losses in the watershed.

(8) No Action. This alternative in effect represents the current situation with its approximate safe yield of 300 mgd.

(9) Connecticut River Flood Skimming. This potential source of supply would utilize water pumped from the Connecticut River during periods of heavy flow. It has been estimated that this action could augment the safe yield of the MDC system by about 72 mgd.

As part of the environmental impact analysis, it will be necessary to develop safe yield values for the alternative plans, including perhaps combinations or variations of the alternative. To accomplish this, it is proposed to use a mathematical simulation model for computer analysis. The program will model the surface water supply alternatives including reservoir storage, streamflow, and interbasin diversions.

The purpose of this report is to review the data that are available and required for the safe yield and streamflow analysis. Section 3 describes the major issues, including the definition of safe yield. In Section 4, the information necessary to model the existing system and the alternatives relating to surface water are described. Section 5 deals with existing data and information, while Section 6 serves to evaluate it. A recommended approach to obtaining the data and information is given in Section 7.

3.0 MAJOR ISSUES

3.1 Overview

The major issues associated with safe yield and streamflow are considered to be the reliability and acceptability of the results of the analysis. These, in turn, will depend on three factors: (1) the quality of the data and information that is used as input; (2) the ability of the model to analyze the real life system; and (3) the utility of the output to readers and users of the report. To put this in another perspective, if the method of analysis and presentation of results were excellent but poor quality input data were used, the output results would be subject to question. Similarly, with excellent data and presentation but with a weak method of analysis, the output would also be weak. And, with both excellent data and analysis but poor output presentation, the persons who must base a decision on the output results would not be well served.

Although the "goodness" of input, analysis and output is fundamental to any problem-solving effort, it is particularly applicable to water resource systems. Input data, such as historic streamflow records, are seldom as accurate and extensive as one would wish. Similarly, there are many methods of analysis that can be used, each having different levels of sophistication, input requirements, and output detail. The presentation of results, although seemingly controllable by the investigator, is not without problems because there is seldom a single, simple answer. For example, the output is probabilistic in form, and the safe yield of a system is a set of values, each having a probability and confidence value associated with it, as well as a set of system constraints associated with the particular analytical computation. Thus each set of output values must be accompanied by a description of how they were obtained and what they mean.

In order to assist the readers and users of this report (and the eventual Environmental Impact Report), the basic concepts associated with the safe yield are described below in Section 3.2. The explanations include simple hypothetical examples, and factors that will be important with respect to the eventual analysis of the MDC System are emphasized. Methods of analysis are discussed in Section 3.3 and streamflow records in Section 3.4.

3.2 Safe Yield

The concept of the safe yield of a surface water system will be explained in four stages using a hypothetical river basin system. Each stage will feature an additional level of the detail that is associated with a complex system.

3.2.1 Safe Yield--Stream Without Reservoir. Assume that we wish to obtain a water supply from a river for some purpose, e.g., municipal supply. Assume also that the water will be withdrawn using a suction pipe placed in the stream, that all of the flow can be withdrawn if desired, that the watershed above the withdrawal point is natural (no other withdrawals, diversions, or control dams), and that there are 50 years of historic continuous streamflow data for the point of interest. The problem is to determine the "safe yield" of the watershed at the point.

First, we must recognize that the safe yield of interest applies to the future flows of water in the river, i.e., during the time of proposed use. Since we do not know what the future flows will be, we must find some way of estimating them. For the system described, it is reasonable to assume that the future flows will be similar to the historic flows, and that we can perform our analysis using the historic record. However, a general rule is that it is important to check the historic events in the drainage area to assure that the historic record can reasonably serve to represent future flows.

Next, let us assume that the entire 50-year flow record for our hypothetical stream has been plotted as a hydrograph showing the discharge as a function of time. One section of this hydrograph is shown in Figure S-1. Note that the time is shown both as the calendar year (January to December) and the water year (October to September). The water year is the normal reporting period for streams in the United States and is selected so as to start and end during the normal low flow periods. The purpose of this is to minimize aberrations in reporting annual streamflow values. However, for the purpose of this discussion, we will use the calendar year.

Note that the discharge is typically low during January and February, then rises markedly during March and April, then declines with low flows occurring in the late summer and early fall. The units of discharge are shown as arbitrary--they would normally be in cubic feet per second (cfs) for the instantaneous discharge rate, but could also be other fairly short term rates such as million gallons per day (mgd). For our purpose, we will simply consider them as "units."

The lowest discharge shown in Figure S-1 during the calendar year is 25 units. If we were to record the lowest flow for each of the 50 years of our hypothetical record, and arrange the values in ascending order, the resulting table might appear as follows:

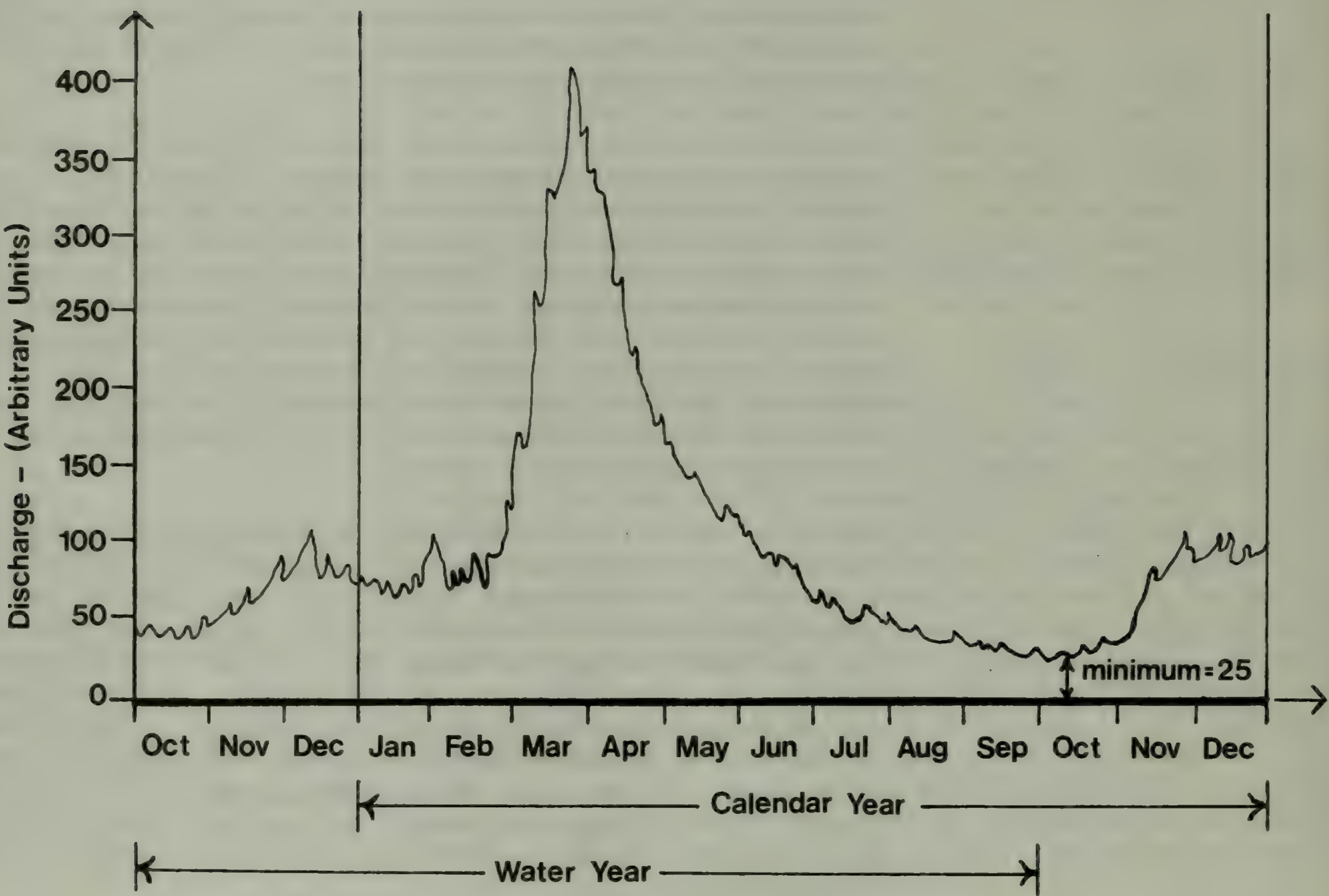


Figure S-1 **Hydrograph for Hypothetical Stream**

Year	m	Lowest Discharge	(N=50 yrs) P
1st lowest year	50	10 Units	0.98
2nd lowest year	49	11 Units	0.96
3rd lowest year	48	12 Units	0.94
4th lowest year	47	15 Units	0.92
5th lowest year	46	20 Units	0.90
.	.	.	.
.	.	.	.
.	.	.	.
49th lowest year	2	79 Units	0.04
50th lowest year	1	80 Units	0.02

The column on the right is the probability, P, that the event will be equalled or that no lower value will occur. P is determined by the equation $P = m/(N+1)$, where m is the number in the data series that represents the number of times that the lowest flow has been equalled or exceeded, and N is the period of record (50 years).

On the basis of this analysis, we can conclude that the safe yield is 10 units with a 98% probability of assurance (e.g., 98 years out of 100), or 11 units with a 96% assurance or 20 units with 90% assurance.

We can also determine, using the principles of probability, what the probabilities are that a selected low flow will occur in any series of years. For example, the probabilities that the lowest flow during various periods will be less than 10 units (using the above example) are:

Period (Years)	Probability that Q<10
1	0.02
5	0.10
10	0.18
25	0.40
50	0.64
100	0.87
200	0.98
500	(1.00)

Thus, if we have selected 10 units as the stated "safe yield" on the basis of our analysis, we should also add that there is a 2% chance that the discharge during any future year will be 10 units or less, and that there is a 64% chance that this will occur in the next 50 years, etc.

(Reference for above probability concepts: Linsley and Franzini, Water-Resources Engineering, McGraw-Hill, 1964.)

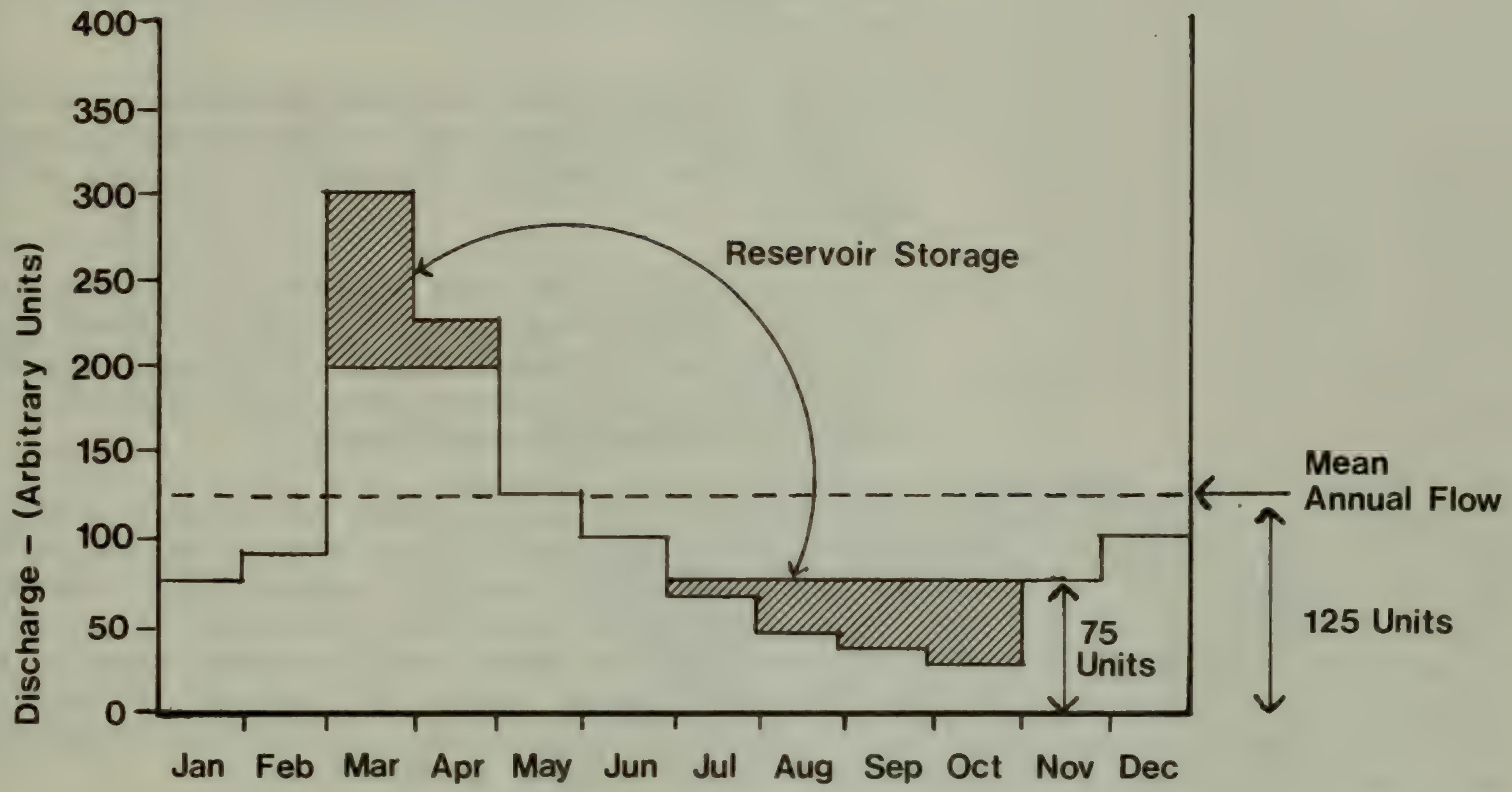
3.2.2 Stream and Single Reservoir, Simple Case. We will now expand our hypothetical water supply system by adding a reservoir on the stream at the point of withdrawal. This will permit us to store some of the heavy spring flows for later use during the dry season. The concept is shown in Figure S-2, in which the instantaneous discharge hydrograph shown in Figure S-1 has been replaced by a histogram showing the mean monthly flows for the example year. This will permit us to perform a reasonable mathematical calculation for the analysis.

In Figure S-2, the cross-hatched portion of the hydrograph for March and April represents the volume of water that has been stored in the reservoir during the spring runoff. The cross-hatched portion of the hydrograph from July through October represents the volume of water released from reservoir storage. The two volumes must obviously be equal (ignoring, for the moment, any losses from the initial storage as a result of evaporation or seepage, and continuing to assume that no downstream releases are required). For the year shown, it can be seen that the safe yield for that year has increased from the 25 units shown in Figure S-1 to the 75 units shown in Figure S-2.

It follows that in order to complete the analysis for the 50 years of historic streamflow record, we could repeat a graphical calculation similar to that described above for each year, then arrange the set of minimum discharges in a manner similar to that discussed in Section 3.2.1 in order to obtain safe yield data for the stream-reservoir system. As long as the proposed reservoir were relatively small (so that it is filled each spring and emptied each fall), each calendar year would represent an independent event for statistical and probability calculations.

It can be seen from inspection of Figure S-2 that by increasing the size of the reservoir it would be possible to increase the minimum withdrawal rate up to the point at which the withdrawal equals the mean annual streamflow. However, as the reservoir gets larger, some storage will be carried "over-year." For example, in order to have withdrawn the 125 units of water shown as the mean annual flow in Figure S-2, it would have been necessary to have had some storage carried over from the previous year to provide withdrawal of 125 units during January and February.

One method that we could use to analyze the safe yield of our hypothetical system using a large (over-year storage) reservoir would be to do a sequential month-by-month calculation for the entire period of record. First we would have to select the size of the reservoir that we proposed to use, then make an assumption about the initial volume of water stored in the reservoir (if any), and finally, we would have to select a trial value for withdrawal. The calculations for each month would then be performed as follows.



igure S-2

Monthly Hydrograph for Hypothetical Stream with Reservoir

(1) Add the volume of monthly stream inflow to the storage that was in the reservoir at the end of the previous month.

(2) Subtract the trial value of withdrawal (expressed as a monthly volume) from the storage volume obtained in (1). Go to step (3), (4) or (5).

(3) If the resulting reservoir storage is zero or greater, but less than the reservoir capacity, proceed to the next month.

(4) If the resulting reservoir storage exceeds the capacity of the reservoir, set the end-of-month storage equal to the reservoir capacity. Proceed to next month.

(5) If the resulting reservoir storage is less than zero, set the end-of-month storage to zero. Make a note that a system failure occurred (in effect, there was insufficient water to meet the trial value of withdrawal). Proceed to next month.

The calculations described above are simple inventory accounting, but they would take some time to perform because 50 years (600 monthly calculations) would be involved for each trial value for withdrawal. If we tested 10 trial withdrawals, there would be 6000 sets of calculations. And, if we wanted to examine 10 reservoir sizes, the number of calculation sets becomes 60,000 (each of which requires at least three steps).

Fortunately, the problem can be solved using a computer in a matter of seconds. Furthermore, the computer program can be written to perform all of the statistical and probability calculations and to provide a finished set of answers concerning the safe yield of the system. The computation, whether or not performed using a computer, is called a mathematical simulation analysis because it simulates the operation of the real system by mathematical methods.

Certain concepts about safe yield can now be added as a result of the above example. In the example, we indicated that a set of trial values of withdrawal would be tested, and the number of failures would be noted for each value. For example, the results of a hypothetical analysis using eleven trial withdrawal rates and four reservoir volumes are shown in Table S-1. The values shown in the table represent the number of times that a failure occurred (the trial withdrawal rate could not be met). Examination of the results might at first glance suggest that the safe yield of the system would be about 80 units for the "1000-size" reservoir, 95 units for the "2000-size" reservoir, 110 units for the "3000-size" reservoir, and 125 units for the "4000-size" reservoir, since these are the withdrawal rates at which failures began to be noticed.

Table S-1

Hypothetical Results--Reservoir Safe Yield Analysis

Trial Withdrawal Rate	Number of Months Having a Failure — Reservoir Capacity 1000	2000	3000	4000
75	0	0	0	0
80	1	0	0	0
85	2	0	0	0
90	6	0	0	0
95	11	1	0	0
100	19	2	0	0
105	36	5	0	0
110	58	10	1	0
115	99	12	3	0
120	151	23	10	0
125	200	48	20	1

However, the analysis was performed using monthly time increments. Thus one failure in 50 years reflects a probability of occurrence of one in 600 monthly events, or a 99.8% system reliability. If, for example, we had decided that the "safe-yield" of the streamflow-without-reservoir analysis (Section 3.2.1) was to be defined as the once in 50 year low flow (P=98%), it might seem reasonable to select the same probability level for the reservoir analysis. If so, we would select the trial withdrawal rate that produced 12 failures as the safe yield. This may or may not be suitable; much would depend on whether the 12 failures occurred separately or whether some occurred during consecutive months.

At this point, the reader may rightly feel that the concept of safe yield has been developed to an unnecessarily complex level. Indeed, it becomes much easier to discuss alternatives if we can associate a single value of safe yield with each plan. This can readily be done, provided that a common set of criteria are adopted and applied uniformly to the analysis of each alternative.

Finally, it will be noted that the safe yield computation is a function only of the streamflow and reservoir capacity; it has nothing to do with municipal demand. In both of the previous examples, we simply determined what constant rate of water could be "safely" obtained for each water supply system, without any consideration of the hypothetical demand. The only way that demand might conceivably enter the analysis would be if there were known seasonal variations, and even in this case such variations would only be used to establish variable rather than constant trial rates of withdrawal.

3.2.3 Stream and Single Reservoir, Complex Case. The previous example was classified as a stream and single reservoir, simple case. The reason for calling it a "simple" case is that the simulation took no account of possible minimum downstream discharge requirements or other losses to the reservoir storage. In real life, these types of physical processes and institutional constraints must be incorporated into the simulation analysis if they could have a significant effect on the results of the analysis. Methods that can be used to accomplish this are discussed next.

- Minimum Discharge: This refers to the minimum releases that must be made from the reservoir to the stream below the reservoir. The minimum discharge rates may be expressed in terms of continuous or daily discharges, and they may vary by month or season. The minimum discharge may also be a function of the rate of stream inflow to the reservoir, e.g., it may be 50 cfs unless the reservoir inflow is less than 50 cfs, in which case the minimum discharge would be the same as the inflow. In other cases, the minimum discharge may be a function of the demand of downstream users or the streamflow at some downstream location. In general, it is a relatively easy matter to incorporate statements into the computer simulation program to account for minimum discharge requirements.

- Reservoir Water Surface Losses: In the simple case, water stored in the reservoir for many months was assumed to be 100% available when needed. In reality, the reservoir storage would be depleted somewhat due to evaporation and augmented somewhat due to precipitation falling directly into the reservoir. The net losses or gains are a function of the month of the year and the water surface area of the reservoir (which in turn is a function of the storage volume). The functional relationships can generally be determined and incorporated into the simulation program to account for the water surface losses.

- Bank Storage: The volume of water in the reservoir, as a function of the water depth or elevation, is normally determined by computations involving the reservoir geometry. However, as the reservoir fills with water, some of the water will seep into the ground along the banks of the reservoir. As the reservoir is drawn down, the water contained in the banks will tend to seep out. In effect, the bank storage adds to the total capacity of the reservoir, although the water stored in the soil is not as quickly available as the free water. Bank storage is probably not significant for analytical purposes and is normally not incorporated in an analysis. However, the concept deserves recognition and should be reviewed for specific sites.

- Dam Seepage Losses: Some water from the reservoir will be lost as a result of normal seepage through an earthen dam and through the soil under the dam. The amount is relatively small and is normally not included in the safe yield analysis. If a minimum discharge from the reservoir is required, the dam seepage (which is collected along the downstream toe of the dam) can contribute to the minimum discharge requirement.

- Minimum Usable Storage: In the simple case, it was assumed that all of the water could be withdrawn from the reservoir if necessary to satisfy the trial withdrawal rate. In reality, reservoirs have some lower level below which water cannot physically be withdrawn (e.g., due to the location of the withdrawal conduit) or below which one would not want to withdraw water for ecological or water quality reasons. Such lower reservoir storage levels can be incorporated into the simulation program, and "failures" are then considered to have occurred if the storage is less than the specified minimum.

- Other Factors: The principal remaining factor that should be considered in the single reservoir complex case is the operating rule. Its role in the simulation analysis will be explained in the next section dealing with multiple reservoir systems. In addition to the operating rule, other factors that may have to be considered include reservoir uses in addition to water supply storage (e.g., hydroelectric power, flood control, limited recreational use, and fish habitat). Without going into detail, these factors can generally be incorporated into the mathematical model, albeit with added complexities.

3.2.4 Multiple Reservoir Systems. In the preceding sections, the discussions have involved a hypothetical single reservoir on a single stream. But as supply systems become larger, water is often stored in several reservoirs. They may be located in series along a single stream, or in parallel along different streams, or both. The concept is shown in Figure S-3, which portrays a hypothetical multiple reservoir system. Reservoir No. 3 is located on Stream A, and Reservoirs Nos. 1 and 2 on Stream B. Streams A and B merge below the municipality being supplied to form Stream C. Water from the reservoirs is delivered to the municipality through aqueducts shown by long dashed lines, and the watersheds for each reservoir are outlined using short dashed lines.

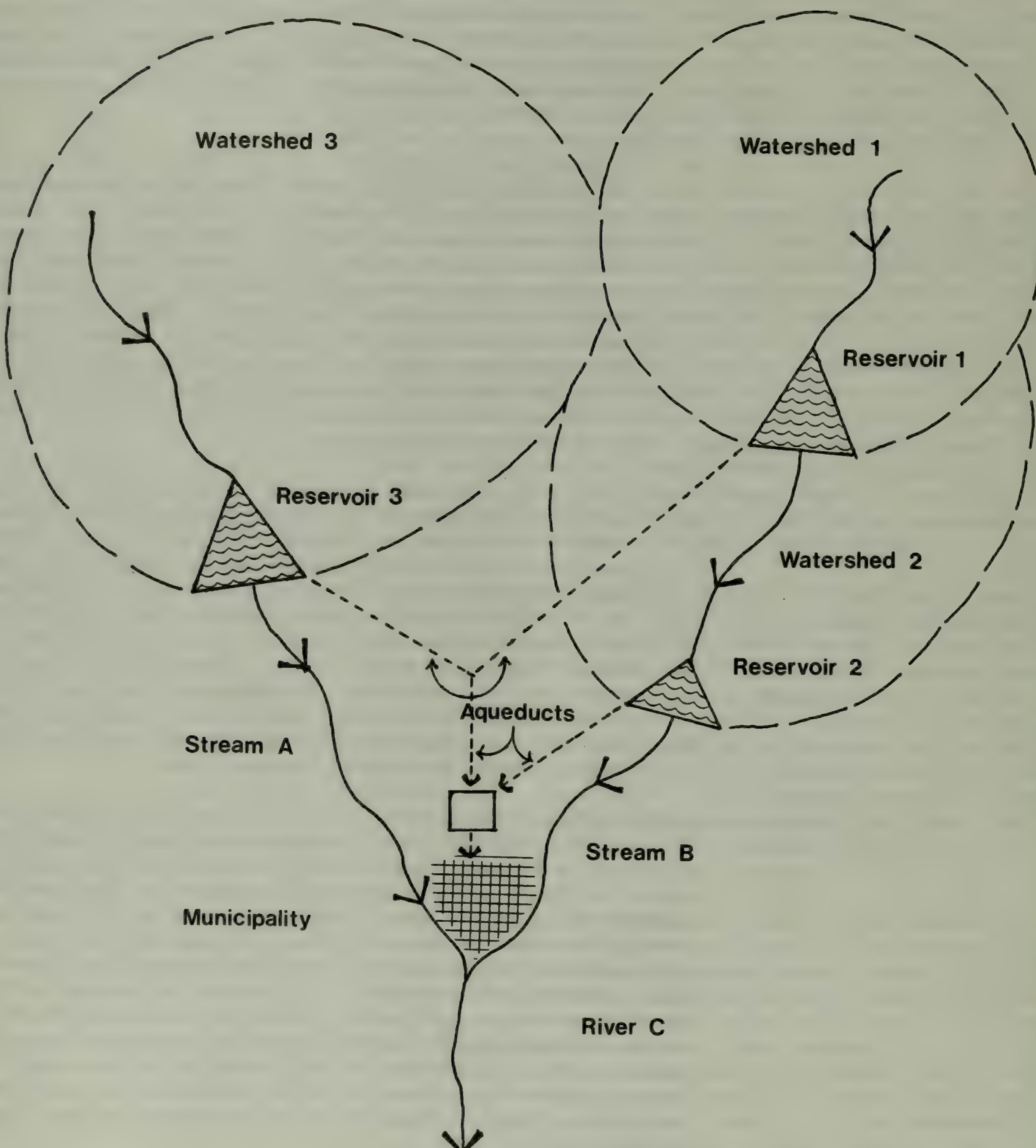


Figure S-3

Hypothetical Multiple Reservoir Supply System

With the aid of this hypothetical water supply system, we will now introduce the concept of the operating rule as a system variable. The operating rule can range from being fairly simple to being highly complex. It serves the purpose of guiding the operations of the system by indicating the rates at which water should be withdrawn from the respective reservoirs and how the reservoirs should be filled during the spring runoff.

For example, because Reservoir No. 1 is upstream of Reservoir No. 2, and hence any overflow or releases from No. 1 will flow into No. 2, it would make sense to withdraw water from No. 2 before No. 1, and to fill No. 1 before filling No. 2. Of course, No. 2 has its own watershed that will contribute to its storage even without releases from No. 1; nevertheless, the idea is to avoid the condition that No. 2 becomes full and any surplus water is lost downstream. A simple operating rule for reservoirs in series is thus to favor emptying them starting with the downstream reservoir and filling them starting with the upstream reservoir.

Reservoir 3, however, is in a parallel configuration with Reservoirs 1 and 2. How should the total municipal water supply be withdrawn, i.e., what percent should come from each reservoir at any particular time? One rule might be to establish the daily withdrawal rate for each reservoir as the ratio of its storage volume on each day to the total system capacity. However, such a rule, although simple, would conflict with the rule for reservoirs in series applicable to Reservoirs 1 and 2.

There is no simple answer for our hypothetical system. In real practice, the operating rule is initially developed during the planning and design phase, and it may later be modified by the operators on the basis of experience.

In order to determine the safe yield of our hypothetical multiple reservoir system using the mathematical simulation technique, it would be necessary to incorporate an operating rule into the computer program. The operating rule can be as complex as we like, and it can be based on a variety of system conditions. With an operating rule in place, the simulation program can be run in the same manner that was described previously, using a range of trial withdrawal rates in order to determine safe yield output.

If we were to change the operating rule and repeat the analysis, we might find that the safe yield output results would also change, becoming either better or worse. The safe yield would thus be a function of the operating rule, and the best solution to the safe yield analysis would utilize a specific "optimum" operating rule. The rule, of course, would have to permit the application of other system constraints, both institutional and physical.

One category of physical constraints are the hydraulic constraints imposed by the "plumbing" that conveys water to the municipality. For example, referring to Figure S-3, the aqueduct from Reservoir No. 2 to the municipality distribution point could only transfer some maximum rate of flow by gravity. The daily volume would be a function of the difference in elevation between the reservoir water surface and the distribution point, and the head losses in the aqueduct and those due to intake structures, valves, regulators, etc.

The safe yield simulation analysis can either incorporate these hydraulic flow constraints in the program, in which case the safe yield becomes a function of the delivery system (in addition to other variables), or the hydraulic constraints can be ignored in the program, in which case the safe yield is independent of the delivery system. The program can also be run in both modes, thereby showing the impact of the hydraulic constraints on safe yield.

Another variable that may affect the safe yield simulation analysis is interbasin water transfers. For example, some water may be withdrawn from a watershed by a user outside of the basin under study, either by pumping or via tunnels. In such a case, the program must be modified to reflect such withdrawals. This can normally be handled by the simulation model, although it may require additional input data and a subset operating rule, both of which must be capable of modeling events in the future years for which the safe yield calculations are to apply.

3.2.5 Safe Yield Variables

In summary, we have seen that the safe yield of surface water systems is a rather complex concept both to calculate and to report. It can depend on the following system attributes:

- Stream inflows
- Reservoir locations and sizes
- Reservoir losses due to evaporation and seepage
- Downstream discharge requirements
- Operating rules and institutional constraints
- Hydraulic constraints
- Interbasin transfers

Once these are defined, the safe yield analysis can be performed by means of simulation using a mathematical model that is executed via a computer program. The results of such a calculation would be a set of withdrawal rates that the system can provide, each with a probability of success. Any change in the system attributes can change the safe yield results; thus any safe yield values that are reported must be accompanied by a description of the system that was analyzed.

3.3 Methods of Analysis

3.3.1 Introduction. In Section 3.2, the method of analysis that was described for determining safe yield was mathematical simulation of the system using a computer program. Prior to the availability of computers, mathematical simulation was an extremely time consuming process, and a variety of other analytical methods were used and will undoubtedly continue to be used in the future. For convenience, we will classify them simply as "non-simulation" techniques.

In general, the non-simulation techniques are applicable to single reservoir supply systems that operate in a non-complex manner. The techniques can be used for estimating total safe yields from multiple reservoir systems by disaggregating the system, but their applicability decreases as the systems become complex, and it is for this reason that a simulation analysis is appropriate for the MDC system. Brief descriptions of some of the non-simulation techniques are given below in Section 3.3.2. In Section 3.3.3, the key programming steps of a simulation model are described.

3.3.2 Non-Simulation Analysis of Safe Yield. Many non-simulation methods have been developed and used over the years to estimate the safe yield of single reservoir water supply systems. No attempt has been made to provide a comprehensive listing of all of these methods, but three techniques are discussed briefly below as examples.

- Mass Curve: This is a graphical method, also called the Rippl Method, in which the inflows to the reservoir (adjusted for downstream releases and evaporation) are plotted as a cumulative volume vs. the period of record. The withdrawal rate, represented by a sloping straight line, is then superimposed on the mass curve plot so that it is tangent to a high point on the mass curve. The maximum vertical distance between the withdrawal line and the mass curve to the right of the point of tangency is the reservoir storage required to provide the withdrawal rate without failure. The mass curve method, in effect, is a graphical solution of the simulation method, but it can be difficult to use for long periods of record and precision can be limited unless a large plot is made. (Note: An example of a mass curve analysis can be found in the Amendment to a Study of the Upper Sudbury River Watershed report by C.E. Maguire, Inc., 1979).

- Stall Method: This method was developed by John Stall of the Illinois State Water Survey and is more comprehensive than the traditional mass-curve analysis. The method was one of three used by C.E. Maguire, Inc., for the Sudbury Reservoir, and it is described in detail in Appendix 2 of the Amendment to A Study of the Upper Sudbury River Watershed report, 1979.

- Regional Watershed Relationships: If the geology, topography and the precipitation amounts and patterns are generally uniform throughout a region, it would be reasonable to assume that the various watersheds within the region would exhibit similar runoff records, and that the safe yield could be expressed as some function of the drainage area and reservoir volume. Such relationships have been developed for the New England area and have been published in graphical form by the New England Water Works Association. This method for estimating safe yield is best suited to smaller watersheds, particularly those for which no streamflow data are available.

3.3.3 Simulation Analysis of Safe Yield. A mathematical simulation model serves to analyze a continuously varying real system by use of discrete time increments. For each time increment, inputs to the system are applied, the response of the system is determined using known mathematical relationships, and outputs are found as changes in the state of the system. The time increments employed must be short enough to permit straightforward response calculations, yet long enough to permit the entire time period of interest to be simulated within reasonable (computer) time.

The simulation program is designed with the aid of a flow chart that shows the sequence of operations. A very abbreviated flow chart for safe yield simulation using monthly time increments is shown in Figure S-4. The chart implies that the program will be executed on a computer, but theoretically it could be solved using only pencil and paper.

The first three steps involve reading of three classes of input data: (1) the streamflow records; (2) data about the supply system, e.g., reservoir capacities; and (3) specific data applicable to the test run, e.g., the range of trial withdrawals.

After the input data have been read, the program executes four iterations each indicated by a "DO" statement. The first "DO" specifies a series of trial withdrawal rates, e.g., 290, 300, 310, 320, 330 and 340 mgd. For each withdrawal rate, the program must perform all of the sequential operations down to the "CONTINUE" statement that applies to the "DO" statement.

The next three "DO" statements cause the program to perform calculations for "NY" (e.g., 50) years of record, for 12 months for each year, and for each of the system components (e.g., reservoirs). For each reservoir, a computation is then made whereby the storage in the reservoir at the end of the month, STOR(M), is determined as the storage at the end of the previous month, STOR(M-1), plus the inflow, QI, plus any transfers, QT (considered algebraically), minus any minimum discharges QD, and minus the trial withdrawal volume, QW.

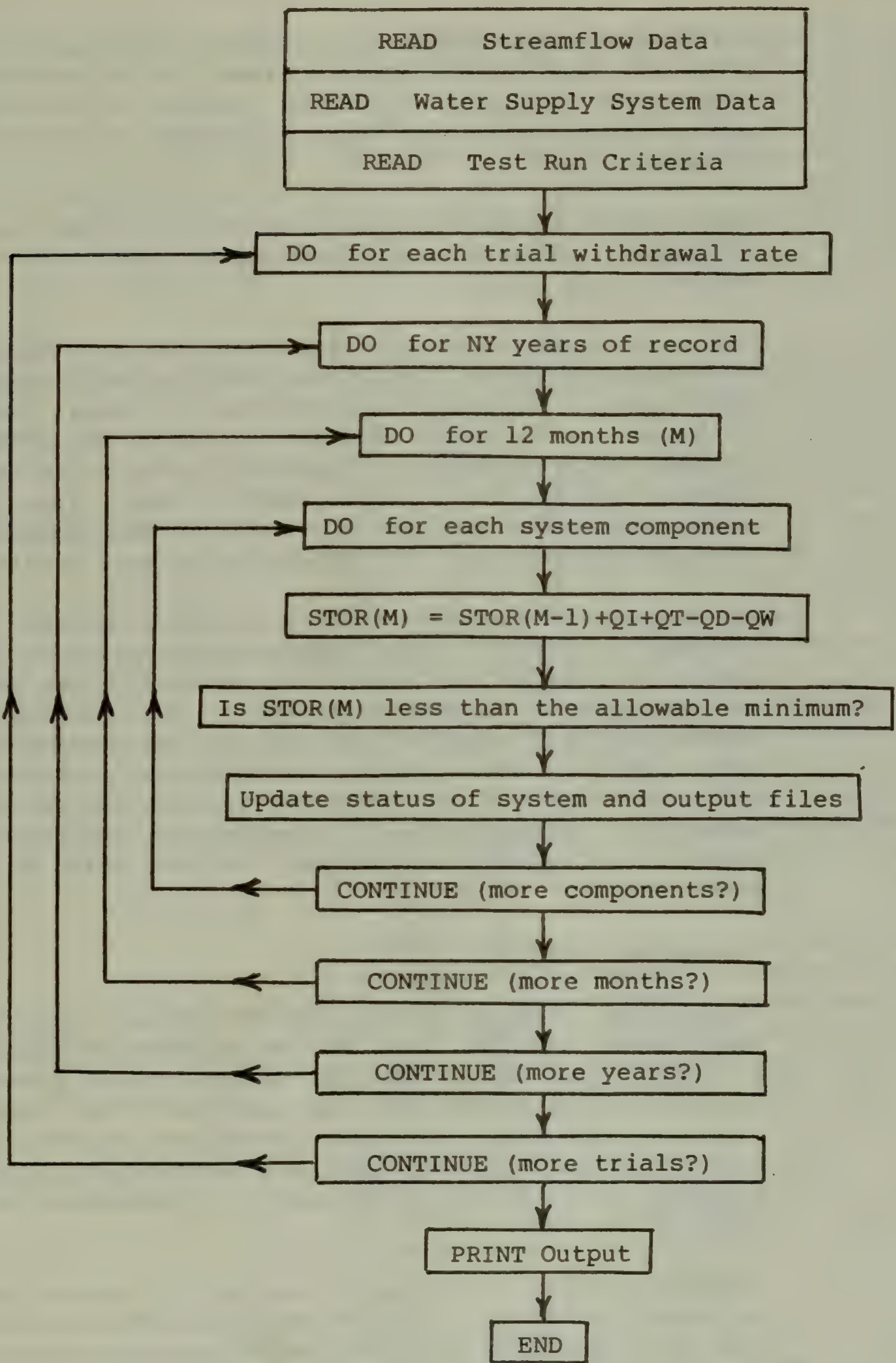


Figure S-4 Computer Simulation Flow Chart

The program then examines the resulting storage to see if it is less than the allowable minimum. If so, a counter is incremented to indicate that a failure occurred. The system status is then updated to prepare it for the next iteration.

The program continues until all of the "DO" loops have been satisfied, following which the output files are printed, and the program ends.

The actual computer program would have far more detail than is even suggested in Figure S-4, but the major steps have been shown. It would be possible to change the time increment, for example, so that for selected months the program would perform the analysis using daily time increments rather than a single monthly step. This type of modification would be appropriate for the MDC system during months when transfers by flood skimming were possible.

In designing a program for a complex system, it is customary to break it into separate subprograms or blocks, thereby enhancing the capability to modify the model by interchanging or adding components. For example, "READ Streamflow Data" might be replaced by a "Generate Synthetic Hydrology" subroutine; or the "PRINT Output" command could utilize a variety of different subroutines to provide detailed or summary output. Other options could be used to provide for batch runs or for analysis using a remote terminal.

3.4 Streamflow Records

In previous sections we treated streamflow records in an ideal sense, that is, that the gaging station was located at the reservoir site, that the period of record was long, and that the drainage area was unaffected by flow regulation or transfers. If these conditions do not prevail, some adjustments must be made to transform available data to apply to the point of interest. A discussion of these concepts follows.

3.4.1 Locational Shift: If a gaging station is located upstream or downstream of the point on the river for which streamflow data are desired, the gaging station records are generally adjusted by ratio of the respective drainage areas. This is equivalent to computing the discharge at the gaging station in units of cubic feet/ second per square mile of its drainage area and applying this to the drainage area at the point of interest. The same method can be used to transform a gaging station record in one river basin to a point of interest in another (nearby) river basin, provided the drainage characteristics and climatologies of the two basins are similar.

3.4.2 Missing Records: Sometimes a gaging station near the point of interest has a relatively short record (e.g., 5 to 10 years), or it may have a fairly long record with a few years missing. In such cases, it may be possible to extend the station's record by regression analysis against the record of some other nearby station that has records for the missing time periods. Several statistical methods, such as serial and cross correlation, may be used in the transforms.

3.4.3 Upstream Regulation and Transfers: Suppose that we have 50 years of record at a gaging station representing actual (observed) flows, but that for the past 20 years there has been a fairly large reservoir in the drainage area that has regulated flows, e.g., storage of spring runoff for later release for hydroelectric power generation. The 50-year record thus contains 30 years of "natural" flow data and 20 years of "regulated" flow data. If we wished to perform a simulation analysis for safe yield at a point near the gaging station, we would recognize that for the future period in which we are interested the hydroelectric reservoir would continue to affect monthly flows. Thus only the 20 years of historic record should be used as a sample of future flows. However, it would be possible to use the entire 50-year period of record if we either adjusted the initial 30 years to reflect the hydroelectric operation or converted the final 20 years into natural flow and included the hydroelectric operation in our simulation model.

Transfers into or out of the basin can be handled in a somewhat similar manner. However, while the preceding example of hydroelectric operations tended only to delay part of the spring runoff until later in the year, the transfer operations would cause an actual increase or decrease in the mean flows at the gaging station.

Another factor in the same general category as transfers would be a change in water use, e.g., introduction of irrigation that would reduce runoff and increase evapotranspiration losses, or changes in the runoff coefficients due to watershed management.

3.4.4 Synthetic Hydrology: Synthetic hydrology is a mathematical technique for generating streamflow records using the statistical properties of existing records. Because streamflows are stochastic in nature, the synthetic hydrology program utilizes a random number generator in its operation. Synthetic records can be useful in that very long records can be generated, thus improving the chances

of examining rare events (e.g., the 200-year drought) in the simulation model. However, if one knew from other records, such as 200 years of precipitaton data, that a 200-year drought event had occurred during the past 50 years, then the historic 50-year streamflow record used for safe yield analysis could reasonably be assumed to reflect the 200-year event.

4.0 NECESSARY INFORMATION

4.1 Basis of Information Needs

The objective is to determine the safe yield of the existing MDC water supply system and of various alternatives that have been proposed to augment the existing supply. In addition, changes in streamflows associated with each of the alternatives are to be reported. In order to make these determinations, a mathematical simulation model needs to be developed and programmed for computer analysis. The input requirements of the program serve to define the data and information that will be necessary.

The simulation program will use monthly time increments and about 50 years of historic streamflow data as hydrologic input. Because certain release or diversion actions are dependent on daily streamflow rates, the simulation program will also examine daily historic flow data for selected months and stations. The mean daily observed discharges for the period of record of all gaging stations of interest are available on magnetic tape from the U.S.G.S. and will be obtained for this study.

Because the safe yield analysis will apply to future years, the simulation program must reflect future conditions to the maximum extent possible. This will require that the historic streamflow data be adjusted if necessary to reflect future conditions. For example, the gaging station at the Shaft 8 intake (Coldbrook) has discharge data from January 1928 to the present. However, since 1955 Fitchburg has at times diverted water from 6.5 square miles of the Ware River drainage basin. This diversion can be expected to continue in the future, but its impact would not appear on the Coldbrook discharge record prior to 1955. The plan, therefore, will be to increase the Coldbrook discharge data after 1955 to include Fitchburg withdrawals (thereby developing a 50-year "natural" discharge record), and then include Fitchburg withdrawals in the simulation program (i.e., subtract the Fitchburg withdrawals from the entire 50 years of adjusted Coldbrook discharge records).

A similar type of adjustment will be made for all gaging station records provided that the activity causing the deviation from natural discharge is included in the simulation program. If the activity is not included in the program (e.g., drawdown of the Connecticut Lakes at the upper end of the Connecticut River), the discharge records will not be adjusted for the effect of the activity, and it will be assumed that the observed discharges adequately reflect future operation of the activity.

4.2 Streamflow Data

Mean monthly stream discharge data that can be used to calculate the inflows to all existing and proposed alternative facilities are required for 50 years (1929 to 1978). In addition, daily discharge records will be needed for stations that control system operations (Coldbrook, Montague City, and one station on the Merrimack River). Mean monthly discharge data will also be needed for some locations downstream of the MDC reservoir system, with selected daily discharge records as well.

4.3 Hydrologic Data Other Than Streamflow

The adjusted streamflow data will be used to determine runoff per square mile of drainage area at the gaging station, which in turn will be used to generate inflows to reservoirs and transfer points. These data will also be used to estimate direct precipitation falling on the reservoir surface. Data will also be needed for estimating reservoir evaporation losses, and for examining the potential effects of bank storage and seepage losses.

Information will also be needed to determine the effect of watershed management techniques on the runoff rates. The information should reflect both the short-term effect (storm runoff) and the long-term effect (infiltration, groundwater storage, and bank seepage that is responsible for base flows).

With respect to potential groundwater supplies, it will be necessary to have some general data on well yields for the area and on aquifer recharge rates. The latter should be correlated to regional streamflow statistics in order to reflect lower well yields during periods of extended droughts. Alternatively, historical precipitation records could be used for the same purpose.

4.4 System Physical Data

For each existing and proposed reservoir and aqueduct, the physical dimensions (e.g., reservoir elevation/area/volume data, hydraulic parameters, etc.) will be needed in order to mathematically determine the volume of water stored, transferred and discharged. For proposed facilities, the site location must be specified. This includes not only reservoirs but also groundwater pumping sites, river withdrawal facilities, and desalination plants. For reservoirs, the minimum pool elevation must be known, whether it is constrained by physical or water quality considerations.

4.5 Operating Rules and Institutional Constraints

Although the system operating rule will be a program variable and hence subject to program definition, some aspects of the operating rule may be fixed externally. An example would be that Ware River water should only be diverted into Quabbin Reservoir because of water quality considerations. Other operating constraints are the legal requirements concerning transfer rates and time periods that affect minimum releases and transfers of water.

4.6 Withdrawal (Demand) Functions

The safe yield analysis is independent of demand; however, each trial withdrawal rate can be seasonally variable rather than being a single constant value. The data needed are the historic mean monthly demands as a function of the mean annual withdrawal. An option that could be used for sensitivity testing would be a superimposed temporary water conservation factor that would only be applied to withdrawals during extreme drought conditions.

The locations of withdrawals must also be specified, as well as the quantity of the total trial withdrawal rate that is to be applied to each withdrawal point. This is partly a function of the system operating rule. For example, when simulating the combined Quabbin-Merrimack system, it will be necessary to know how much of the trial withdrawal rate is to be taken from each supply source as a function of the season and other system conditions.

4.7 Stage-Discharge Relationships

In order to determine the reduction in overbank flooding due to flood-skimming operations, it will be necessary to know river and flood plain cross sections for selected locations and to have river stage versus discharge functions for each location.

5.0 EXISTING INFORMATION

5.1 General

Existing information about facilities falls into two general categories, one dealing with existing facilities and the other with proposed (future) facilities. Information about the former is available from construction plans and other historic records and is generally complete and fixed. Information about proposed facilities can be found in planning studies and is usually sufficiently detailed for safe yield analysis. Proposed facilities, however, are normally described using several alternative plans for development, any one of which could be modified during actual design. For this reason, each safe yield analysis must clearly describe the future facilities that were incorporated in the analysis, as well as their associated operating rules and constraint criteria. The latter are sometimes not as well defined in study reports as are the physical characteristics, or they are at least subject to greater variation.

5.2 Streamflow Data

A list of gaging stations that will or may be used in connection with the simulation analysis is shown in Table S-2. The locations of the stations are shown in Figure S-5. Mean daily discharge data (observed) are available on magnetic tape from the U.S.G.S. for the period of record of each station. The listing omits several stations in the upper Merrimack River basin which may have to be included in order to analyze the Merrimack River-Continuous Withdrawal alternative.

In order to develop the natural inflows to Quabbin, Wachusett and Sudbury Reservoirs, it is planned to use a mass balance method. The historic monthly inflows to each reservoir will be determined as the volume of water that would have been required to account for the change in storage, aqueduct withdrawals or additions, and downstream releases. These data are available and complete for the period that each reservoir has existed. Inflows determined in this manner, called watershed yields, include such factors as evaporation, seepage losses, and direct precipitation.

5.3 Hydrologic Data Other Than Streamflow

Direct data on reservoir evaporative losses and seepage losses are not available except to the extent that they are reflected in watershed yields. Monthly evaporation rates, determined from pan measurements, are available but may not be fully transferable to large areas. Nevertheless, they provide a reasonable basis for estimating evaporative losses.

Seepage losses through dams can be estimated from measurement of downstream discharge less any known reservoir discharge. No data on bank storage are known to exist, although some theoretical estimates can be made.

Information about the effect of watershed management on runoff has been reported by Mrazik, Mader and MacConnell (Mrazik, et al., 1974), based on a six-year study (1967-1972) along Cadwell Creek in the Quabbin Reservoir watershed. The report concluded that annual increases in water yield in the order of 20% could be obtained by an integrated management system which removes only one third of the original forest cover on the watershed. It is uncertain to what extent their experimental results could be applied to the entire watershed.

Groundwater data for the Plymouth aquifer is contained in two reports: Hydrologic Data of the Coastal Drainage Basins of Southeastern Massachusetts, Plymouth to Weweantic River, Wareham, published by the U.S.G.S. in cooperation with the Massachusetts Water Resources Commission, 1977 (Massachusetts Hydrologic Data Report No. 18), prepared by John R. Williams, Gary D. Tasher, and Richard E. Willey; and Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Plymouth to Weweantic River, Wareham, Hydrologic Investigations Atlas HA-507, published by the U.S.G.S. in cooperation with the Massachusetts Water Resources Commission, 1974, and prepared by John R. Williams and Gary D. Tasher. Estimates are also available from the NEWS studies.

5.4 System Physical Data

Data on reservoirs, aqueducts and other hydraulic controls are available for existing facilities. Similar data for proposed facilities are generally available from survey and planning reports, and it is expected that these data will be supplemented as part of the EIR study.

Table S-2

Selected Discharge Gaging Stations

	Station No.	Location	Drainage Area (sq. mi.)	Years of Record (to 1978)
	Connecticut River			
1.	1670	Turners Falls	7,163	63
2.	1705	Montague City	7,865	74
3.	1840	Thompsonville, CT	9,661	50
	Millers River System			
4.	1615	Tarbell Brook	18.2	62
5.	1620	Near Winchendon	83	62
6.	1625	Priest Brook	19.4	62
7.	1632	Otter River	34.2	13
8.	1650	E. Branch, Tully River	50.4	63
9.	1653	Lake Rohunta Outlet	20.3	13
10.	1655	Moss Brook	12.3	62
11.	1665	Erving	375	64
	Chicopee River System			
12.	1725	Ware River, near Barre	55	32
13.	1730	Ware River, Coldbrook	96.8	50
14.	1735	Ware River, Gibbs Crossing	199	66
15.	1740	Quabbin Watershed, Hop Brook	3.39	31
16.	1745	Quabbin Watershed, near Hardwick	43.7	41
17.	1746	Quabbin Watershed, Cadwell Creek	0.63	17
18.	1749	Quabbin Watershed, Cadwell Creek	2.81	17
19.	1755	Swift River, West Ware	188	27
20.	1760	Quabog River, West Brimfield	151	66
21.	1770	Chicopee River, Indian Orchard	688	50
	Nashua River System			
22.	0944	N. Nashua River, Fitchburg	63.6	6
23.	0945	N. Nashua River, Leominster	110	43
24.	0955	S. Nashua River, Clinton	107.7	83
25.	0965	Nashua River, East Pepperell	433	43
	Merrimack River			
26.	0920	Goffs Falls (below Manchester, NH)	3,092	42
27.	1000	Lowell	4,635	55
	SUASCO River System			
28.	0970	Assabet River, Maynard	116	37
29.	0975	Sudbury River, Framingham	75.2	103
30.	0995	Concord, River, Lowell	405	42

Source: U.S. Geological Survey, Water-Data Reports, 1978.

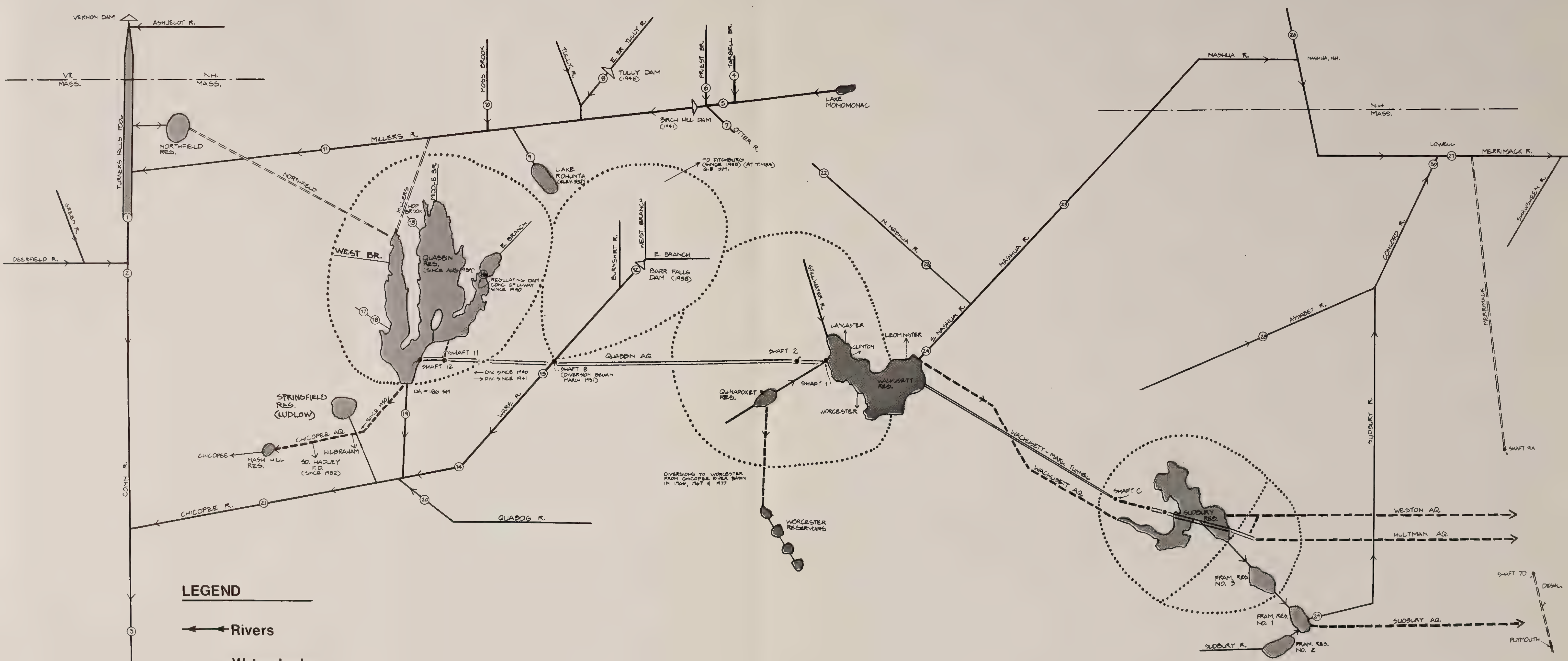
FIGURE S-5

Schematic Diagram of MDC System

Northfield Water Supply Project EIR (Phase I)

Metropolitan District Commission

Wallace, Floyd, Ellenzweig, Moore, Inc.
Architects / Planners



LEGEND

Rivers

Watersheds

Tunnels

Aqueducts

5.5 Operating Rules and Institutional Constraints

Data required to define these variables are available for existing facilities, and they have been defined for proposed facilities. There will always be some uncertainty about how future institutional constraints may be legislatively or judicially established, but various hypotheses can be examined as part of the simulation analysis.

5.6 Withdrawal (Demand) Functions

Data are available on the historic withdrawal patterns, and the locations of withdrawals outside of the greater Boston area are known. It can reasonably be assumed that future seasonal withdrawal variations will follow historic patterns. Future locations and volumes of withdrawal are less certain, particularly for demands by Worcester and other central Massachusetts communities. However, it is expected that such withdrawal schedules will be formulated as part of the demand study, and the resulting scenarios can be tested in the simulation analysis.

5.7 Stage-Discharge Relationships

These data require a substantial effort to develop for an entire river length. River channel and overbank flood plain cross sections must be used in conjunction with an open channel flow model (for steady state discharge) or a flood routing model (for non-steady state discharge). If the event of interest is overbank flow, it is expected that some existing data are available from Corps of Engineers flood control studies, or from flood plain zoning studies. However, the adequacy of existing data will depend on the exact locations of interest. An alternate approach would involve only the calculation of the approximate difference in elevation in the flood stage as a result of various flood skimming diversions. These changes could be calculated for a range of typical river cross sections and slopes. The advantage would be that no massive set of site specific data would be required, yet a reasonably accurate portrayal of typical changes in river stages could be provided.

6.0 EVALUATION OF DATA AND INFORMATION

6.1 General

The terms "data" and "information" can be contrasted by defining data as a collection of numerical values that have been obtained from some type of measurement. Information, on the other hand, refers to anything that informs us about something except for data, e.g., maps, photographs, text, etc. In reality, data are a subset of information; however, the two terms are often used interchangeably.

Data and information can be classified in many ways, two of which are useful for the purpose of this study: (1) by subject matter (as has been done in Sections 4 and 5); and (2) by the time to which they apply, either the past (historic) or the future. Historic data are characterized as being the result of past observation and measurement, while data that apply to the future must be developed by some rationale which includes a measure of uncertainty. The latter may be expressed by some probability function or simply "high, median and low" estimates.

Data and information can be evaluated using four characteristics:

- Quantity--This refers to the completeness of the data. For gaging stations, it includes both the number of stations, the period of record, and whether the record has any missing sections.

- Quality--This is a measure of the reliability of the data, both with respect to accuracy and precision.

- Applicability--This deals with the relevance of the data to the problem at hand. Applicability may be lessened because the data do not apply to the exact time and place of interest, or because a parameter other than the primary one of interest was measured.

- Transformability--Basic data measurements can be termed raw data, and they must often be converted to another form for use. For example, the raw data for gaging stations is generally a river stage, which is transformed to a flow rate. The latter may be further transformed to natural flow by adjusting for upstream regulation and/or diversion, in which case additional data would be required to complete the transformation.

6.2 Streamflow Data

Of the 30 gaging stations of potential interest listed in Table S-2, 16 have periods of record of 50 years or more, and 24 have at least 30 years of record. Records for reservoir regulation and diversions are generally complete for the period of their operation.

It would be desirable to develop a 50-year record of mean monthly discharges adjusted for regulation and diversions within the MDC supply system. This would create a "natural" streamflow record to be used as input to the simulation model. The data required to do this are generally good, although some extension by correlation will be required for the earlier years at certain locations such as the Swift River. Reservoir inflows that are estimated by the mass balance technique will be adjusted for evaporative losses. The algorithm used to make this adjustment will later be used in the simulation analysis, thus any error in the algorithm will tend to be self cancelling.

6.3 Hydrologic Data Other Than Streamflow

Reservoir evaporation rates will be estimated from existing pan evaporation data. Good data on bank storage and dam seepage are not known to be available, but approximations can be made. Any errors in such approximations are not expected to have any significant impact on safe yield calculations, since dam seepage would contribute to minimum discharge requirements, and bank storage is not a system loss of water but rather has a time lag effect. Precipitation on the reservoir surface can either be incorporated in the surface evaporation algorithm, or estimated separately as a function of mean monthly stream discharge.

Data concerning increased runoff yields due to the application of watershed management techniques are provided by the experimental studies conducted in the Cadwell Creek watershed (Mrazik, et al., 1974). Additional information is needed on the applicability of those results to larger areas of the drainage basins and to longer time periods.

Groundwater data for the Plymouth aquifer is reasonably good for the period that includes the record drought of the middle 1960's (Williams, et al., 1977; Williams and Tasher, 1974). The major data uncertainty with regard to this source may be in the extent to which the aquifer can or should be developed, that is, the impact on water quality and other local sources of supply if large quantities of water were withdrawn from the aquifer.

6.4 System Physical Data

Data on the existing system are good. Data on the proposed alternatives are generally good, and additional data are expected to be developed during the study.

6.5 Operating Rules and Institutional Constraints

The historic operating rules and existing institutional constraints are known. For some applications, the existing rules and constraints can be expected to apply to the future, e.g., the Swift River minimum discharge, the Ware River diversions, or the Connecticut River flood skimming criteria. In other cases, particularly with some of the alternatives, rules and constraints will have to be based on the best information contained in other study reports and modified if necessary to reflect any new information developed during the progress of the study. For example, withdrawals from the Merrimack River may be a function of the storage in Quabbin and Wachusett Reservoirs, as well as the discharge in the Merrimack River. In general, it is believed that sufficient information is available to develop rules and constraints for the alternative supply systems.

6.6 Withdrawal (Demand) Functions

Adequate data are available from historic records to develop future seasonal demand patterns. The distribution of withdrawals along the MDC supply system will require that supplies for the Chicopee area, the Worcester area, and Fitchburg be specified, either as fixed rates or as functions of the total trial withdrawal rate.

6.7 Stage Discharge Relationships

Although the changes in mean daily discharges can be determined for downstream locations as a result of flood skimming withdrawals, data are not known to be readily available to convert discharges to river stages for the entire length of the rivers involved. Stage-discharge curves are expected to be available for selected points, such as at gaging stations or at municipalities where flood control studies have been made. However, it would be possible to develop a set of representative cross sections for the river reaches of interest in order to estimate the impact of flood skimming operations. This would be particularly appropriate as an initial step, since it would provide a measure of the sensitivity of the flood plain to changes in discharge rates.

7.0 RECOMMENDED APPROACH

7.1 General

The data and information that will be required for the safe yield and streamflow analyses are integrally connected with the simulation model for which they will serve as input. For this reason, it is recommended that the simulation model be developed in conjunction with data collection, thereby facilitating the identification of specific data needs, the transformations required, and the format that the data should have for use as computer input.

The recommended approach consists of two parts that would culminate with a completed simulation model together with all of its baseline data stored in computer files. The model would then be ready to perform safe yield analyses for any specified scenario of alternative supply facilities and system operating assumptions. The two parts are described next.

7.2 Part One--Program Definition and Data Collection

This part contains four steps. Step one would be to prepare a schematic diagram of the system to be modeled, showing streams, reservoirs, aqueducts, gaging station locations, withdrawal points, etc. A rough sketch has already been drawn and is shown as Figure S-5. The intent of step one would simply be to convert into a finished tracing from which copies could be made. The schematic drawing would serve as an aid in explaining the system to both the study team and to other interested parties.

The second step would be to obtain the mean daily streamflow discharges for all gaging stations for their period of record on magnetic tape from the U.S.G.S. These data would then be used to obtain mean monthly discharges as a subset file. In addition, data about reservoir storages, releases, and basin transfers would be obtained. All of these data would then be used to generate a set of natural discharge rates for the catchment areas of the MDC system.

The third step would be to outline the simulation program as a detailed flow diagram, including subroutines that would handle such tasks as input data storage and retrieval, reservoir operating algorithms, output routines, etc. This step would also serve to identify, name and dimension input, output and program variables, and to this extent, it would provide the "compartments" to contain the data.

The fourth step under Part One would be to collect the other data (non-streamflow related) that are required by the model. These data would include hydraulic constraints, operating rule and institutional constraint data, evaporation and seepage data, etc. All data would be identified as to source and other characteristics.

7.3 Part Two--Program Development

This part would serve to bring the simulation program up to the point of being ready for use, and it involves three additional steps that continue from those in Part One. Step five would be to write the computer program that was outlined in step three, and to debug it using dummy test data if necessary.

Step six would involve testing the program using historical conditions, including actual annual withdrawals. The object would be to check the operation of the model by applying its natural streamflow input to its various operating algorithms, and comparing the reservoir storages calculated by the model to those that existed historically. If differences occurred, the cause would be determined and appropriate adjustments to the transformed input data or program algorithms would be made.

Step seven would be to document the model and its baseline data. The model would then be ready to use for the safe yield and streamflow analysis. The model at this stage could serve as a useful operational tool for the current MDC system, even in the absence of any future water supply augmentation. Indeed, it is hoped that it would eventually find use for the analysis of the water supply (or western end) of the MDC system, just as the excellent distribution model that has been used for the eastern end (Camp Dresser & McKee, Inc., 1975).

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QUESTIONS, COMMENTS AND RESPONSE TO DRAFT TECHNICAL MEMORANDUM

Page numbers cited below refer to the pages in the final technical memo.

Q: Page 2, Introduction. A chart listing all data available would be helpful. Upper Sudbury Watershed--how will data from Parsons-Brinkerhoff be incorporated into ADL's estimates? Connecticut River Tributaries--the three alternative plans should be spelled out. (NCAC memo 6/15/80)

A: The available data are both voluminous and complex, and it would be difficult to prepare a comprehensive chart at this time. However, the data will be presented in a chart or other appropriate form in subsequent reports.

The Parsons-Brinkerhoff data (Sudbury Reservoir environmental report) will be reviewed and any pertinent data will be adopted where possible. However, the Sudbury Reservoir will be treated independently as a component of the MDC supply system within the proposed simulation model.

The three alternative plans for the Connecticut River Tributaries supply source are described in the Northeastern United States Water Supply Study (NEWS), Millers River Basin Water Supply Project report, prepared by the Corps of Engineers (Draft, March 1973). The alternatives are:

No.	Name	Estimated Yield
1	Millers River Diversion	68 MGD
2	Tully-Millers Diversion	76 MGD
3	Tully Complex Diversion	48 MGD

Each alternative would involve transfer of water to the Quabbin Reservoir. Additional details can be found in the NEWS reports, and will be provided in subsequent phases of the MDC environmental study.

Q: Page 3, Connecticut River Flood Skimming. A precise definition of "flood skimming" must be provided; the use of the phrase "heavy flow" seems too general here. (NCAC memo 6/15/80)

A: The intent of the Introduction was only to provide a brief summary of the alternative plans, with the expectation that detailed descriptions would be presented elsewhere in Phase One reports. The term "flood skimming" refers to the withdrawal and transfer of some of the water flowing in a river during periods when the flows exceed average flows by some amount. The minimum flow rate, below which transfers would not be made, is typically less than the flow rate that would represent the start of a flood stage in the classical sense, and to this extent the use of the word "flood" in "flood-skimming" may be misleading. Nevertheless, "flood-skimming" is the term that has been used to denote the withdrawal and transfer of above-normal streamflow, and readers should recognize it in a conceptual rather than a literal sense. The details of any flood-skimming plan (e.g., the Connecticut River via Northfield, or the Merrimack River), can be complex and must be completely defined for each plan. Such information will be provided for each of the flood-skimming plans to be investigated in this study. The term "heavy flow" was used to signify the discharge in the Connecticut River at Montague City Gaging Station above which Northfield Mountain transfers could occur, namely 17,000 cubic feet per second. The term was used only in the context that stream flows are categorized into "low," "average," and "heavy" flows.

Q: Page 6, Figure S-1. What is the source for the "hydrograph for hypothetical stream?" Was this hydrograph developed for the New England area? (NCAC memo 6/15/80)

A: The hydrograph was only intended to illustrate the hypothetical safe yield concept that was developed in the text. However, it is representative of New England streamflows to the extent that discharges are high during the spring and low during late summer and fall.

Q: Page 12, Reservoir Water Surface Losses. Some data on evaporation may be obtained from Colonell and Higgins (1971) Hydrologic Factors in the Determination of Watershed Fields, while precipitation data for Quabbin and Wachusett are available from the MDC Water Division. (NCAC memo 6/15/80)

A: The comment is acknowledged.

Q: Page 15, definition of "operating rule." It appears that this definition is combining natural and man-made phenomena. Filling of reservoirs reflects natural processes, while withdrawal reflects demand, need, or regulation. (NCAC memo 6/15/80)

A: This is normally the case for individual reservoirs. However, in the MDC system, water taken from the Ware River at Coldbrook can be diverted to either the Quabbin or the Wachusett Reservoirs (although in practice it is always sent to Quabbin). To this extent an operating rule is required for filling as well as releasing.

Q: Page 15, paragraph 2. The Reservoir numbers are backwards: Reservoir No. 1 is upstream of Reservoir No. 2. Furthermore surplus is only "lost" for human consumption, but not in terms of the ecosystems downstream. (NCAC memo 6/15/80)

A: Reservoir numbers 1 and 2 have been corrected in the text. The word "lost" was intended to apply only to human consumption, i.e., the municipal water supply use.

Q: Page 15, paragraph 6. Both institutional and physical constraints must be spelled out for analysis of safe yield. (NCAC memo 6/15/80)

A: Agreed. Each safe yield analysis and output must include all factors (assumptions, rules, constraints, etc.) that were included (or excluded) in the model.

Q: Page 16, paragraph 3. Can the impact of flood control reservoirs be handled by the simulation model in the same manner as interbasin water transfers? (NCAC memo 6/15/80)

A: During floods, reservoirs in New England are operated by the Corps of Engineers on essentially an hour-to-hour basis using telemetric data covering river stages, precipitation, reservoir levels, etc. The operation is unique for each flood event, but the general principle is to release stored water as soon as possible after it has been impounded in order to regain the benefit of having floodwater storage space, but not so fast as to aggravate any uncontrolled downstream flooding. The entire flood control operation is likely to be over in less time than one month, and to this extent the action is not "seen" by the simulation model which operates using monthly time increments. However, the historic mean monthly streamflow data, used as input to the model, includes the effects of the operation of flood control reservoirs.

Daily streamflow records, which will be available on magnetic tape, will be examined in order to estimate the volumes of water that could be transferred. These daily discharge records will also reflect the effect of the flood control operations for historic flood events. The simulation model, as presently envisioned, will not include any routine that directly incorporates the operation of flood control reservoirs. However, their operation will be included indirectly to the extent that their operation influenced stream discharge records.

Q: Page 16, Safe Yield Variables. The following system attribute should be added to the list. "Rate of sedimentation of a reservoir" (e.g., Northfield Mountain, Quabbin, Wachusett, or Sudbury). (NCAC memo 6/15/80)

A: Rate of sedimentation would be a system attribute to the extent that it decreased the volume of a reservoir as a function of time. It was not included in the belief that sedimentation rates for the MDC reservoirs were too low to cause any significant change in volume during the period of interest. However, additional data will be sought to clarify the matter.

Q: Page 21, Missing Records. The statistical methods to be used in transforming records should be clearly spelled out. (NCAC memo 6/15/80)

A: The statistical methods to be used will be selected on a case-by-case basis and after review of the statistical parameters of each station's record. The procedures used will be defined in subsequent reports.

Q: Page 21, Upstream Regulation and Transfers.

a) How would the final 20 years of hydroelectric operation be converted into "natural flow?"
b) Where would records of water use for irrigation be obtained? (NCAC memo 6/15/80)

A: The observed streamflow for the final 20 years would be converted to natural flow by determining the change in storage in the reservoir for each month, then adding (subtracting) that volume to the observed monthly streamflow for the month. The resulting streamflow is thus the flow without the influence of the reservoir, or the "natural" flow.

Irrigation was only mentioned as an example of activities within a watershed that could affect the total runoff from the watershed (assuming that the water were withdrawn from streams within the watershed). Irrigation is not believed to cause any significant effects on the MDC watersheds, and no irrigation records will be sought.

Q: Page 22. Climatic trends (such as the general rise in temperature reported by Dr. P.T. Ives during the last 140 years) must be taken into consideration in developing a simulation model. (NCAC memo 6/15/80)

A: If we knew how climatic trends had affected the streamflow records for the past 50 years, and if we felt that the trends would continue for the next 40 years, we could incorporate this variable in the simulation model. At present, we do not believe that climatic trends would have a significant effect on the safe yield analysis, but the question can be tested by sensitivity analysis using the model. We will contact Dr. Ives during subsequent work to obtain additional information.

Q: Page 23, 4.1, paragraph 2. Why not use mean daily discharge data for the simulation program? (NCAC memo 6/15/80)

A: The MDC reservoirs are large enough that daily fluctuations in streamflow have no significant impact on safe yield. Monthly streamflows are used, therefore, to reduce computer running time. However, daily streamflows will be used to determine the fraction of the monthly streamflow that can be diverted during certain months of the year, such as from the Ware River at Coldbrook. A preliminary data preparation program will be used for this purpose. If at some time during the safe yield study it is found necessary or desirable to use the daily streamflows as input to the simulation model, it would be possible to do so.

Q: Page 23, 4.1. Paragraph 3. What conversion factor would be used to "increase the Coldbrook discharge data after 1955 to include Fitchburg withdrawals?" (NCAC memo 6/15/80)

A: The actual estimated monthly water transfer obtained by Fitchburg would be used.

Q: Page 23, 4.1. Paragraph 4. Are there lists of all activities causing deviation from natural discharge for all rivers (including the Connecticut, Millers, Merrimack, and Sudbury systems)? (NCAC memo 6/15/80)

A: Factors affecting the observed flows at each gaging station are noted in the U.S. Geological Survey Water-Data Reports under the heading "Remarks."

Q: Page 24, 4.2. Streamflow data. Where are mean monthly stream discharge data described for 50 years? (NCAC memo 6/15/80)

A: The word "described" should read "required," and the text has been so changed. The discharge data are published annually by the U.S. Geological Survey.

Q: Page 24, 4.3. Hydrologic Data other than streamflow, paragraph 1. Consultants should confer with Dr. Lawrence Dingman, Associate Professor of Water Resources, James Hall, University of New Hamsphire, Durham, New Hampshire 03824 about methods of calculating "runoff per square mile of drainage area." (NCAC memo 6/15/80)

A: Dr. Dingman will be contacted in subsequent phases of the study. It should be noted that runoff per square mile of drainage area, expressed as a mean value, would be used for a general comparison to simulation model analysis, but cannot be used as direct input to the model. For example, the water diverted to Quabbin from the Ware River watershed is only a partial use of the runoff from the Ware River watershed, and it is subject to both time and flow rate constraints. There is no way to determine the transferred volume except to inspect the historic discharge record at the point of diversion.

Q: Page 24, 4.3. Hydrologic data other than streamflow, paragraph 2. Consultants should confer with Dr. Tom Rice, Department of Geology, University of Massachusetts, Amherst, Massachusetts 01003 for information on "groundwater storage and bank seepage." (NCAC memo 6/15/80)

A: Dr. Rice will be contacted during subsequent phases of the study.

Q: Page 24, 4.3. Hydrologic data other than streamflow, paragraph 3.

a) Consultants should confer with Dr. Ward Motts, Department of Geology, University of Massachusetts, Amherst, Massachusetts 01003 for information on "potential groundwater supplies."

b) Consultants should confer with Dr. Philip T. Ives, Department of Biology, Amherst College, Amherst, Massachusetts 01002 for information on "historical precipitation records." (NCAC memo 6/15/80)

A: Dr. Motts and Dr. Ives will be contacted during subsequent phases of the study.

Q: Page 25, 4.5, Operating rules. The "legal requirements concerning transfer rates" should be spelled out. (NCAC memo 6/15/80)

A: The legal requirements will be spelled out in subsequent reports, after copies of all of the laws and regulations have been obtained and reviewed.

Q: Page 26, 5.1, General. In describing "the future facilities that were incorporated in the analysis," will various scenarios be developed? (NCAC memo 6/15/80)

A: The basic scenarios to be developed are those that have been listed as the alternatives for this study. Each alternative may also have some variations possible, e.g., the three plans for the Millers River Basin diversions. Each scenario that is analyzed for safe yield will be described in the report.

Q: Page 26, 5.2, Streamflow data. It would be helpful to the reader to have the phrase "mass balance method" defined. (NCAC memo 6/15/80)

A: Mass balance, as used in paragraph5.2, refers to the law of conservation of mass. For a reservoir, this can be expressed as:

Inflow - Outflow = (Change-in-storage)

or:

Inflow = Outflow + (Change-in-storage)

For example, if we ignore direct precipitation on the surface of the reservoir (an inflow) and evaporative loss (an outflow) and groundwater exchanges, the inflow (as streamflow) to a reservoir must equal the outflow (discharge to downstream plus any withdrawals) plus the change in volume (mass) in the reservoir for the period of interest. Thus, if the outflow during a month amounted to 1000 units of water, and the reservoir volume (mass) increased by 200 units, the inflow would have to have been 1200 units. The mass balance equation can be made more sophisticated by including precipitation, evaporation, and groundwater seepage, but all water mass must be accounted for. If we assume that water is an incompressible fluid, then we could substitute "volume" for mass." This is the case for reservoir analysis; nevertheless, it is the convention in hydrological analyses to use the basic term "mass balance."

Q: Page 27, Table S-2. Sources for all information should be included on the table. (NCAC memo 6/15/80)

A: The source reference has been added to the table.

Q: Page 29, 5.3. Hydrologic data, paragraph 1. From whom are "pan measurements" available? (NCAC memo 6/15/80)

A: Pan measurement data are available from the U.S. Geological Survey and the National Weather Service.

Q: Page 29, 5.3. Hydrologic data, paragraph 3. The "unknown document" should be identified and cited properly. (NCAC memo 6/15/80)

A: The text has been modified to identify the reference.

Q: Page 29, 5.4. System Physical Data. What is the adequacy of "data for proposed facilities" which "are generally available from survey and planning reports?" (NCAC memo 6/15/80)

A: See paragraph 6.4, page 32.

Q: Page 30, 5.7. Stage-Discharge Relationships. River channel cross sections may be available from Massachusetts DPW or Massachusetts Fish and Wildlife. (NCAC memo 6/15/80)

A: The comment is acknowledged.

Q: Page 32, 6.2. Streamflow Data. It would appear to be <u>necessary</u> "to develop a 50-year record of mean monthly discharges adjusted for regulations and diversions within the MDC supply system." There is a need to look at the historical impact of present MDC diversions in the Connecticut River system (from the Swift River) and on the Sudbury River downstream of the diversion sites. (NCAC memo 6/15/80)

A: The safe yield analysis can be performed using an historic record of any reasonable length. The length of the record determines the precision of the analysis; e.g., a 100-year record would provide a safe yield for the once-in-a-hundred-year drought (99% assurance); a 50-year record, the once-in-fifty-year drought (98% assurance); and a 10-year record, the once-in-ten-year drought (90% assurance). For the MDC analysis, 50 years was selected as reasonable record on the basis of availability of streamflow records and a desire to use as long a record as possible. Other record lenghts, e.g., 45 years or 55 years, could also be used with only a small change in the associated degree of assurance.

The historical impacts of present MDC diversions would be difficult to assess. The Quabbin Reservoir, the newest one in the system, began operation in the early 1940's, while the Sudbury Reservoir was completed in 1898. The assessment of impacts from historical diversions, even those for the past year, would require that a baseline be established to represent the "without action" scenario. But no such real-life scenario exists from which to obtain baseline data. If one were to try to postulate the impacts on streams from which some water had been diverted, it would only seem reasonable to complete the analysis by evaluating the impacts associated with the water that had been diverted, that is, the water that constituted the MDC supply. If such supplies had never become available, one has to postulate that either alternate supplies would have had to have been developed (creating their own impacts), or that water users would have had to get along with less and less water per capita, or that population growth failed to take place. Such studies could be interesting, but they are outside the scope of the present investigation.

Q: Page 32, 6.3. Hydrologic Data, paragraph 1. "Estimates" of precipitation may not be appropriate since detailed records of precipitation at MDC reservoirs are available from MDC's Water Division. (NCAC memo 6/15/80)

A: Agreed. Actual precipitation data are preferred and will be used.

Q: Page 32, 6.3, paragraph 2. Sources of information on watershed management techniques should be properly cited. (NCAC memo 6/15/80)

A: The source has been referenced.

Q: Page 32, 6.3, paragraph 3. All sources on "groundwater data for the Plymouth Aquifer" should be listed. (NCAC memo 6/15/80)

A: Sources on groundwater data have been referenced.

Q: Page 33, 6.4 and 6.5. It would be helpful to the reader if "data on the existing system" and the "historic operating rules and existing institutional constraints" were itemized in chart form. (NCAC memo 6/15/80)

A: See response to question 1.

Q: Page 33, 6.7. Mass DPW, Mass Fish and Wildlife or the U.S. Corps of Engineers may have cross sectional data for "the river reaches of interest." (NCAC memo 6/15/80)

A: The comment is acknowledged.

Q: Page 34, 7.1, General. Where will the computers files for simulation model be stored? (NCAC memo 6/15/80)

A: At the completion of the study, the computer files together with program documentation will be delivered to the MDC. It is expected that the program and data files will then be stored on the Massachusetts DPW computer which the MDC uses.

Q: Page 34, 8.2, paragraph 1. The rough sketch which has already been drawn should be included here. (NCAC memo 6/15/80)

A: The sketch has been reproduced as Figure S-5.

Q: Page 34, 7.2, paragraph 2. If both daily and monthly data are available, why not use daily for the simulation model? After mean daily streamflow discharges are plugged into the system, why not add daily data for all components of the present system? Such modelling should be done for each of the four seasons of the year. (NCAC memo 6/15/80)

A: See response to question 13 (page 23, 4.1, paragraph 2).

Q: Page 35, 7.3, paragraph 2. Since data for daily withdrawals are available, why use "actual annual withdrawals?" (NCAC memo 6/15/80)

A: Using daily as opposed to monthly or annual withdrawals would not help to check the model for safe yield purposes, since daily fluctuations in either inflow to or withdrawal from the reservoirs are insignificant for large reservoirs. The important point with respect to checking the model is that the historical record of withdrawals be used in conjunction with the historical record of streamflows. This

is contrasted to safe yield analyses for future time, in which case a single fixed value of withdrawal is analyzed using the historical streamflow record.

Q: Page 35, 7.3, paragraph 3. The distribution model developed for the eastern end of the MDC system should be adequately referenced. (NCAC memo 6/15/80)

A: The reference has been included.

Q: Selected Bibliography, page 1. The consultants may wish to cite Dr. Dingman's work on storage-yield relations in New England. (NCAC memo 6/15/80)

A: The works by Dr. Dingman that were reviewed were in unpublished form, and hence not cited. We will contact Dr. Dingman to obtain published references, which will be included in subsequent reports.

Q: Selected Bibliography, page 2. The Brower and Walford Model Zeta paper appeared in 1979 in the Connecticut River Watershed Council Valley Newsletter No. 4: 9-10. (NCAC memo 6/15/80)

A: The reference has been incorporated in the bibliography.

Q: How is watershed management accounted for in the model? (NCAC meeting 6/6/80)

A: Ideally, the surface runoff per square mile of watershed being managed would be increased by some fraction as a function of the month of the year. This factor would then be incorporated into the model so that surface water inflows to the reservoir would be increased accordingly. However, the adjustment must also take into account any associated changes in infiltration to groundwater, which could affect low flows several months later. Alternately, if the decrease in interception (on tree leaves) and in transpiration were known, this volume of water could be added to the historic runoff per square mile from the watershed from the areas that were being managed. The model would be run for safe yield analysis with and without the watershed management runoff adjustments in order to estimate the effect of the alternative on safe yield.

Q: How do we account for groundwater movement into reservoirs? (NCAC meeting 6/6/80)

A: Before a reservoir is constructed, the groundwater that would later flow into the reservoir appears as part of the streamflow in streams within the reservoir's catchment area, and it accounts for the low flows that occur between rainfalls. By using the pre-reservoir streamflow records, the groundwater component is automatically included. After the construction of a reservoir, the apparent monthly inflows to a reservoir can be determined using the known change-in-storage and the outflow volumes by means of a mass-balance computation. The apparent inflow automatically includes all inflows (stream, groundwater and direct precipitation) and losses (groundwater outflow, evaporation), thus accounting for groundwater flows for the period of record during which the reservoir was in existence. Thus, both periods of the historic record (pre-reservoir and post-reservoir) will account for groundwater movement.

Q: Regarding watershed management: Are there any aquifers in the Quabbin watershed? Have they been studied by the MDC? (NCAC meeting 6/6/80)

A: Groundwater favorability maps for various regions of New England have been prepared by the U.S. Geological Survey. The map for the Lower Connecticut River Basin (Cederstrom, D.J. and Arthur L. Hodges, Jr., Hydrologic investigations Atlas HA-249, 1967) shows that within the Quabbin watershed there is only a small area that is "generally favorable for development of 0.5 million gallons a day or more per well of groundwater from sand and gravel aquifers." This area is located north of Quabbin reservoir and extends into the Millers River drainage basin near Athol. The remaining part of the Quabbin watershed contains a few strips in Class 2, defined as "generally unfavorable for development of large groundwater supplies," while the major part of the watershed is Class 3, which "generally yield small supplies of groundwater sufficient only for stock and domestic use."

It should be noted that any effort to tap groundwater supplies within a reservoir watershed could prove to be non-productive since the groundwater would normally contribute to the watershed yield.

Q: Define mass balance. (NCAC meeting 6/6/80)

A: See response to comment 22 (page 26, 5.2, NCAC comments).

Q: Is someone calculating the yield for a 50-year drought? (NCAC meeting 6/6/80)

A: The safe yield analysis will use 50 years of historic streamflow as input, and to this extent the safe yield of the system being analyzed can be considered to be the yield for the 50-year drought. In a theoretical sense, we cannot be sure that the results reflect the 50-year drought or not, since the 50-year drought is one that occurs on the average of once in 50 years. If, for example, we had 500 years of historic streamflow record available, we could search for the drought that was equalled or exceeded (in dryness) for 10 times, and call that the 50-year drought level. During any given 50-year period, the theoretical 50-year drought may or may not be included, as may any other frequency drought. For example, even the once-in-a-1000-year drought occurs during some 50-year period. In the case of the Quabbin analysis, we know from precipitation records (which are available for 100 years) that the worst drought occurred in the middle 1960's, and to this extent we can assume that the 50-year streamflow record from 1929 to 1978 included the 100-year drought.

Another problem in defining any drought is that droughts are long-term events, unlike floods that are comparatively short and easy to measure. A three-month drought during which time no precipitation occurred could be disastrous to farmers and to communities having small reservoirs, but may have no significant impact on a reservoir such as Quabbin that is capable of over-year storage. Conversely, 10 years of sub-normal precipitation could have more of an effect on the Quabbin yield than on other water users. Thus the "50-year" drought can only be defined in the context of the water supply system under investigation.

Q: Does the model address the impact of a drought experience on users? Recovery rates? (NCAC meeting 6/6/80)

A: The model only serves to determine the safe yield of the existing system and the alternatives. As long as the demand does not exceed safe yield, there should be no impacts due to droughts on the users, unless a drought that is more severe than the

"50-year" drought occurs. The model could be used to estimate the impact on the supply of water under the more severe drought conditions. To do this, the hydrologic input would have to be reduced to reflect the more severe condition (probably by developing a synthetic streamflow generator). The model could then show the number of months that demand could not be fully met and the extent of the deficiency. The model would not show the specific impacts of the droughts on the users, nor on their recovery rates.

TECHNICAL MEMORANDUM:
EVALUATION OF INFORMATION
TO ASSESS THE DEMAND MANAGEMENT
(CONSERVATION) ALTERNATIVE

Prepared by
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CONSERVATION

SUMMARY

Water conservation is defined by the study as any action to reduce water use. It includes measures to prevent the "wasteful" use of water as well as the promotion of the wise and efficient use of water.

The literature review identified three types of conservation measures - as described by the New England River Basins Commission, Urban Water Conservation Project: those which improve the supply and distribution system in order to reduce waste -- such as leak detection and repair; those which provide incentives for consumers to reduce usage -- including price level and rate structure revisions, educational programs and regulations, use restrictions, and plumbing code revisions; and, those which actually reduce usage -- such as retrofitting with low flow plumbing fixtures, installing pressure reducing valves, changing water using habits, and implementing systems which reuse or recycle water.

Many sources of information were identified including articles from the theoretical literature, reports of experience elsewhere in the nation, and Massachusetts communities reported to have implemented conservation programs. National experience seems to indicate that while significant short-term reductions can be achieved during emergencies (such as the California drought in the 1970's), experience with programs to achieve long term reductions in demand as an alternative to new supply under non-crisis circumstances are more limited. Locally, the majority of communities appear to have achieved the most significant cut-backs through leakage detection and repair programs.

The available information appears to document a wide variety of achievements from various conservation programs - ranging from no perceptible results to upwards of 60% consumption reduction reported in part of Marin County, California during the drought. However, none of these can be transferred directly to expectations for this area because of the varying circumstances under which they were implemented.

The literature review has led to a conclusion that further analysis will be required before a reasonable estimate can be made of the potential water savings that might be achieved through implementation of conservation measures in the study area.

In order to develop a range of expectations for demand alteration in the study area, the study must: 1) analyze the components of program experience elsewhere and compare the circumstances to those in the study area; 2) hypothesize reasonable conservation programs or combinations of programs; and, 3) assess the range of potential reductions which might be achieved in the residential, industrial, commercial, institutional, and unaccounted-for water categories to be defined under the "Demand/Use" Task. Information is available to analyze the first two steps and assess potential reductions under step three. The data must be developed on actual present usage by category in the study area, however, in order to have realistic baseline amounts of water consumption which might be reduced through conservation programs directed at different categories of use.

INTRODUCTION

This literature search is intended to define the tasks required to develop a "range of expectations for demand alteration from programs encouraging water conservation and recycling for domestic and non-domestic users." These levels of potential reductions will be used to develop a series of demand projections which reflect the impact of alternative conservation programs.

In order to estimate the potential water savings from alternative demand management techniques, it is necessary to identify the components of present water use. Therefore, this task is an integral part of the work being developed under the Demand/Use Task. The Demand/Use Memorandum, referred to frequently here, describes the effort to characterize usage by category.

Water conservation refers to both direct measures which reduce water use and to programmatic actions which encourage consumers to reduce water use. It includes techniques which prevent the "wasteful" use of water or which promote the "wise and efficient" use of water.

In this study a wide variety of conservation measures have been identified. These are conveniently grouped into: supply improvement techniques, incentive measures, and actual water use reduction techniques. (These definitions rely on the work of the New England River Basins Commission, Urban Water Conservation Project, Vol. II, Review Draft, March, 1980.)

<u>Supply Improvement Techniques</u>:

These measures are implemented by the water supplier. They improve the efficiency of the water delivery so that waste is minimized during collection, treatment, transmission,

and distribution. Measures include: metering, leakage detection and repair, watershed management, evaporation suppression, main pressure reduction, and use of devices to prevent illegal hydrant openings. The techniques are an extension of management and maintenance operations and require no direct cooperation on the part of the water user.

Reviews of the information for assessing the potential impacts of supply improvement techniques are found in other technical memoranda: leakage and unmetered water is covered in a separate memorandum in which main pressure reduction and evaporation suppression are considered for study during Phase II; and watershed management is discussed in the technical memorandum: Assessment of Data for Ecology-Reservoirs, Local Supplies.

This memoradum examined information to assess the techniques described below which are designed to reduce consumption through action by the water user. They include incentive strategies and actual reduction techniques. The methods may be directed equally at domestic and non-domestic users, but assessments of the impacts will be made separately for different categories of users as described in the methodology. These techniques are referred to in this memo as demand management techniques.

Incentive Strategies

These techniques do not directly reduce water use but are designed to cause the user to do so. They include:

Price level and rate structure changes: There are many pricing designs which encourage conservation. All base user charges on the cost of the water consumed. The literature does not agree on which are most effective. Those which do not encourage conservation are:

- Flat Rates - fixed charges per billing period regardless of consumption. Fixture rates - flat rate which increases according to number of household plumbing fixtures but is unrelated to actual consumption.

- Tax Revenue - Tax revenues for operation of the water department come from property taxes through a municipality's budgetary process and users are not charged the actual cost of the water.

Implementation of a new rate structure which relates directly to the amount of water consumed, or a price level increase, can induce reductions in demand.

Regulations: These are legal measures designed to reduce water use. Included in this group are: Restrictions and/or bans of certain uses - usually designed to modify peak demands caused mostly by outdoor uses such as lawn sprinkling; plumbing code and building code measures requiring installation of water saving appliances; and the extreme - rationing, usually reserved for emergency situations.

Education: This includes all methods designed to make users aware of the benefits of a conservation program and to explain how the user can accomplish cutbacks or implement selected techniques.

Use Reduction Techniques

Water conservation methods which actually lead to use reductions include:

Water saving fixtures: These are physical devices which alter the conventional plumbing system design in order to reduce water used in their operation. They range from plastic disc flow restrictors for faucets and showers and toilet tank dams to composter toilets which use no water at all.

Pressure reducing valves (PRV's): These devices may be installed in individual services - usually on the supply line next to the meter - and can make dramatic water savings through reduction of excessive pressures. Larger PRV's installed in the distribution main servicing a group of households would make greater savings by reducing system losses to undetected leakage. The potential impact of these larger PRV's will be part of the analysis under the unmetered water section.

Changes in user habits: These are techniques which call for the consumer either to use less water to perform the same task, to do the task without water, or to perform the water-using task less often or not at all. The techniques are directed at washing, bathing, kitchen use, garden watering and car washing. The changes require an educational campaign.

Reuse/Recycling Systems: These either reuse the same water for more than one function or recycle it for reuse in the same function. A wide variety of these systems are common in industrial procedures or in cooling processes and they are often custom-designed for particular users. In residential use there is less experience and systems are costly for the individual household. A new study by Murray Milne, however, reports that residential on-site water reuse systems are technically feasible and environmentally

sound. They may become economically attractive because of increasing energy costs for pumping and treatment in centralized water and sewerage systems (Milne, 1979). In addition, a special demonstration project for reuse of laundry grey water has been funded this year by the Massachusetts Division of Water Pollution Control (Interview with Warren Kimball, Division of Water Pollution Control, 4/2/80). Results of the project will probably not be available for this study.

MAJOR ISSUES AND METHODOLOGY

The main issue to resolve is how to make a realistic estimate of the range of potential impacts from the implementation of the demand reduction programs listed above. A review of the theoretical literature on these measures and reports of experience elsewhere is insufficient to enable a realistic estimate of possible use reductions in MDC user communities.

Although dramatic reductions have been achieved during crisis situations, experience with long-term reductions in demand are less well documented. It is also difficult to determine which element of a conservation program is most effective in reducing demand. Under drought emergency conditions such as occurred in California, actual changes in residential user habits were effective. In Massachusetts, on the other hand, there are several examples of education programs to stimulate changes in user habits which have not achieved the same levels of success. Supply improvement techniques have been most successful in reducing rates of consumption over time.

Successes and failures of conservation programs reported elsewhere range from Marin County's renowned 67% reduction in water use as a result of an aggressive water conservation campaign during the California drought of 1976-77 to a predrought program (1972-6) of public education in the same area which had no measurable impact. Other reports include Denver's variable experience with a 9-11% reduction, and Elmhurst, Illinois' experience where a multi-faceted program in effect since 1976 resulted a 15% overall reduction (NERBC, Vol. II, 1980). The Massachusetts Water Supply Policy Statement estimated that consumption could be reduced by 15-20% over a 10 year period through a program of public education, plumbing code revisions, pricing powers, and unspecified public ordinances (WFEM, 1978).

The analysis must identify the components of these and other programs and the effective causes of use reductions reported. A method must be devised for matching these experiences to the characteristics of water demand in the study area. In addition, the selection of conservation strategies must take into account some of the legal and institutional constraints under which the MDC operates.

The method of analysis will be to hypothesize reasonable strategies from the literature and stipulate ranges of potential demand reduction expectations. The demand management scenarios to be projected will be selected on the basis of at least the following criteria:

- There has been documented experience with the method.
- The method has actually been successful in reducing demand.
- The method has achieved a general level of acceptance.

A list of scenarios will be refined which reflect increasing levels of effort and impacts on demand. A tentative list of such scenarios is planned for assessment:

1. Present usage patterns and projections with no demand management reductions (described in Demand/Use Memorandum).

2. Rate structure revisions and price increase impacts on residential use and industrial use. Several measures will be reviewed and selected for analysis if they are shown to have demonstrated effectiveness. One scenario might include the impact of sewer charges and pretreatment requirements under the Clean Water Act of 1977. It is anticipated that the study will focus on the following measures:

   - excess use pricing;
   - sliding scale pricing; and
   - ration pricing for emergency conditions.

3. Regulations:

   - The impact of recent plumbing code change (effective in 1978) to require maximum 3 gpm shower heads in new and renovated residential units;
   - The impact of proposed code changes to require 3.5 gallon toilet tanks in new and renovated residential units; and,
   - The impact of emergency bans on outside usage.

4. An education program directed at residential user habit changes.

5. A retrofitting program including low flow showerheads, toilet tank inserts and faucet aerators in residential units; and low flow showerheads in group quarter residential use and hotels.

6. Selected industrial conservation programs using process changes, reuse and recycling systems which have demonstrated effectiveness.

7. The installation of pressure reducing valves at individual residences where pressure exceeds 50 psi.

The following section describes these programs and a preliminary evaluation of the data necessary to assess the impact of their implementation in the study area.

DATA NEEDS AND SOURCES FOR IMPACT ASSESSMENTS OF DEMAND MANAGEMENT MEASURES

Three major studies summarize most of the theoretical literature on conservation methods and compile data from actual experience with programs implemented elsewhere in the country. The primary sources reviewed in these studies will be referred to as the conservation scenarios are refined during the next phase.

- New England River Basins Commission, Urban Water Conservation Project, Before the Well Runs Dry, Volumes I and II, Review Drafts, March, 1980;

- Santa Clara Valley Water District, San Jose, California Report on a Water Savings prepared by Metcalf and Eddy, Palo Alto, California, May, 1976; and

- U.S. Army Corps of Engineers, Baltimore District, Effects of Water Conservation and Impacts of Water Supply Deficits in the Washington Metropolitan Area, prepared by Robert Taylor and Charles P. Bristol, Water Resources, Engineers, an operating unit of Camp, Dresser and McKee, Inc., Springfield, Virginia, April, 1979.

Three additional kinds of information have been identified:

- Reports from other areas where conservation programs have been tried.

- Experience of local communities with conservation programs, including restrictions during the drought.

- Present and projected water use characteristics for the study area communities.

The latter will be evaluated in the Demand/Use Technical Memorandum. Each conservation measure, however, will require additional secondary sources and special study area data as follows:

Incentive Strategies

1. Price Level and Rate Structure Changes.

   The following rate structures are described in the literature as being effective for water conservation. The list is taken from the New England River Basins Commission, Urban Water Conservation Project, literature search (Volume II, "Supporting Research", pp. 104-5).

Pricing Structures Oriented Toward Modifying Peak Demands: (usually caused by outdoor uses such as lawn sprinkling)

- excess use pricing (price level significantly higher for all water used above an average amount, usually determined by winter use);
- seasonal pricing (summer price levels are higher than winter price levels);
- daily peak load pricing (price levels higher during hours of peak use); and,
- marginal cost pricing (both short-and long-term).

Pricing Structures Oriented Toward Modifying Average Demands:

- uniform unit pricing (price per unit is constant as consumption increases);
- increasing block pricing (price per unit increases as consumption increases);
- lifeline pricing (price level kept low for "necessary" consumption, then increases);
- scarcity pricing (price of depleting supply attached to existing price); and,
- sliding scale pricing (price level per unit for all water increases as average daily consumption increases).

Pricing structures oriented toward recovering actual costs of supplying the individual user:

- spatial pricing (user pays for cost of distribution system needed to serve him);

- average variable pricing (price per unit will vary according to actual expenditures within fixed period of time);

- hook-up fees; and,

- service charges.

Other pricing structures that have been mentioned in the literature include: water "stamps" (subsidies to low income users); tax incentives for implementing other conservation techniques; and tax credits for using other conservation techniques.

The literature on these methods addresses local retail pricing strategies. Since MDC is primarily a wholesaler, a careful review of legal and institutional options and constraints must be included in the analysis. The MDC charges $240/million gallons of water to their user communities in the district (see Appendix A). Outside the District, rates charged user communities vary according to the terms of the contractual agreements. Each community then sets its own rate structure for charges to consumers. Under Section 27 of Chapter 92, the MDC is required to approve the "minimum" water rates set by communities supplied. Appendices B & C lists the rates charged by communities.

The potential effect of altered rate structures, therefore, very much depends on the ability of the MDC to influence pricing strategies of local water departments. This is an issue to be addressed in the analysis of pricing strategies.

Another issue raised by the literature search is the price elasticity of water. Although a wide range is reported (0.1 to 1.5), most recent studies found very low elasticities (0.1 to 0.3). These studies need to be reviewed critically to determine the situation most likely to prevail in the MDC supplied areas.

A series of rate structure and level scenarios will be selected for assessment. These will be hypothesized based in part on existing or potential MDC authority and in part on prevailing practices elsewhere. The impact assessment will address such issues as:

- Potential effect of rate structures versus rate level;

- potential differential effect on industrial, residential, commercial usage;

- effect of MDC versus local pricing;
- peak versus total pricing; and
- "normal" versus drought period pricing.

2. Regulations.

Plumbing Code Changes: State regulations were revised in 1978 to require low flow showerheads in new construction and renovations. The Massachusetts Plumbing Code (248 CMR: Board of State Examiners of Plumbers and Gas Fitters), regulations filed with the Secretary of State prior to December 23, 1977, Section 2.14(8)(f) require:

"Conservation of hot water. 1. Showers: Showers used for other than safety reasons shall be equipped with approved flow control devices to limit total flow to a maximum of 3 gpm per shower head.

EXCEPTION: This requirement shall not apply to installations where showers are supplied with two or three valve diverters.

2. Lavatories in restrooms of public facilities shall:
   - -Be equipped with outlet devices which limit the flow of domestic hot water to a maximum of 0.5 gpm.
   - -Be equipped with devices which limit the outlet temperature to a maximum of 110° F.
   - -Be equipped with metering faucets that limit delivery to a maximum of 0.25 gal. of hot water."

In addition, legislation has been offered again this year by the Special Legislative Commission on Water Supply to limit toilets in new and renovated construction to those using only 3.5 gallons/flush. (Special Legislative Commission, 1979.) It has been estimated that flow-limiting shower heads can decrease household water consumption 12%. (Metcalf & Eddy, 1979.) Efforts will be made to document and refine this expectation. To assess the impact on residential use, the study will need the following information:

Residential Use Assessment

Data Needs	Sources
- Estimated Reductions from Devices	- Literature sources and experience in

	Washington Suburban Sanitary Commission program (WSSC)
- Household use	- Demand/Use task
- Rate of new residential unit construction	

Outside Use Restrictions: These restrictions are applied to reduce peak usage in an emergency situation. An estimate of a percentage reduction in outside use from an enforced ban on lawn watering, car washing and swimming pool filling will be made. This will be a theoretical estimate of the potential and will not be projected over time as such a regulation would not be a realistic measure for reducing long-term demand.

Residential Use Assessment

Data Needs	Sources
- Estimated household use reductions	- National Experience elsewhere - Local experiences simulating drought (e.g. Ipswich & Dedham) where efforts have been made to reduce peak usage. - Local Drought experience (Reported in: Kates, Arey, and Russell, Baltimore, Drought and Water Supply for Resources for the Future, Johns Hopkins Press, 1970).
- Present outside residential usage	- Demand/Use Task - Comparison of winter usage to summer usage by community.

- New England River Basins Commission, Evaluation of Domestic Central Water Use in New England, prepared by Curran Assoc. Inc., Boston, MA, December 1976.

3. Educational Programs/Changes in Use Habits.

   Documentation of experience with use reductions from an educational program alone is rare. Usually the program is an essential adjunct to the implementation of another conservation program such as retrofitting with lowflow plumbing devices, outside usage bans or price changes. Therefore it is difficult to isolate the impact of this variable. An effort will be made to estimate the potential impact of an educational campaign directed solely at changing water using habits.

Residential Use Assessment

Data Needs	Sources
- Estimated household use reductions	- Experience elsewhere - Literature
- Household use	- Demand/Use Task

Water Reduction Techniques

1. Retrofitting Existing Plumbing Fixtures with Water Saving Devices.

   Residential assessment: In addition to the assessments made for water saving fixtures in new construction and renovation, (see Regulations: Plumbing Code Changes, page 10) a scenario will be developed for projecting the impact of installing the following flow reducing devices in existing units:

   - toilet tank inserts;

- shower heads or flow restrictors; and

- faucet aerators or flow restrictors.

These are selected for the amount of experience with their use and their level of acceptability.

Residential Use Assessment

Data Needs	Sources
- Estimated household use reductions	- Literature sources and program experience elsewhere. (e.g. Milne, 1976; Metcalf & Eddy, 1976)
- Indoor residential use	- Demand/Use Task

Institutional Use Assessment: A scenario which included retrofitting institutional dormitories with low flow showerheads could be assessed.

Institutional Use Assessment

Data Needs	Sources
- Group quarters, per capita use	- Census data and Demand/Use task estimate
- Potential Reduction in per capita use	- U. Mass, Amherst (Water Savings NOVA Showerhead" project - 1975 - Sharpe & Fletcher, Penn. State, 1977. - Other literature sources

<u>Commercial Use Assessment</u>: An estimate will be made of the potential impact of faucet aerators or automatic shut-offs in commercial use if present hotel usage can be developed from the data.

Commercial Use Assessment

Data Needs	Sources
- Commercial use by type	- Demand/Use Task
- Assessment of potential savings	- Walter Newman case study in Falmouth for the NEIWPCC, 1979

2. <u>Industrial Process, Reuse/Recycling Techniques</u>.

   There are many devices suitable for water conservation in industrial processes such as multiple rinse tanks, counterflow rinses and fog nozzles. There are also methods for recycling and reuse of both process and cooling water. However, the costs and suitability of these measures must be custom-designed for the type of industry and process. Until more information is developed on actual industrial use under additional services, a demand management scenario cannot be planned.

   Sanitary use by industrial employees is a small fraction of industrial use. If figures are available as industrial usage is analyzed, a scenario may be developed to project the impact of using low flow devices to reduce this portion of industrial use.

3. <u>Pressure Reducing Valves</u>.

   The Washington Suburban Sanitary Commission (WSSC), Cabin John Project, reported water savings in excess of 30% when pressure reducing valves were installed on 83 single family homes. The homes were in an area where system pressures ranged between 70 and 120 psi. Pressure reducing valves controlled house pressures at 50 psi. Pressure reducing valves were installed in each home, so the pressures in water mains remained

unchanged. Therefore, any leaks in mains would still be driven by the same high pressure. If PRV's had been installed in mains, it is reasonable to assume that more water would have been saved because of less main leakage.

Field studies performed in the mid-sixties by researchers at Johns Hopkins University showed similar results. These results are reported in Linaweaver, Report on Residential Water Use Research Project by the Dept. of Sanitary Engineery JHU, for the Office of Technical Studies Architectural Division Federal Housing Administration, 1963. Results are also reported in the Journal of the American Water Works Association, March, 1967 (Linaweaver, 1967). The City of Johannesburg, South Africa performed similar studies but documentation of the results was not located.

The Office of Technical Services, American Water Works Association, was contacted. Mr. George Craft of that office was unaware of any additional studies regarding demand as a function of system pressure.

Residential Use Asessment:

Data Needs	Sources
- Number of residential units served with excessive water pressure	- Unaccounted for Water Task -- Water Department interviews
- Potential household use reductions	- Washington Suburban Sanitary Commission - Literature references (e.g. Linaweaver, 1967) - Interviews with Boston Water and Sewer Commission re: planned demonstration project in West Roxbury funded by Mass. Div. of Water Pollution Control, and impact of Dorchester Tunnel on service pressures.

During Additional Services, the scenarios will be refined and grouped in such a way as to develop a series which reflect graduated levels of effort.

SOURCES

Experience from the conservation programs in the following areas will be reviewed. The selection was developed from the literature review, the NERBC Urban Conservation Project, Survey of New England Suppliers, and from interviews with the NCAC and other public participants in the study.

National Programs

Denver, Colorado	-	Public education and outside watering restrictions, 1972 - present. 1974-5 water use down 9%.
Elmhurst, Illinois	-	Public education; pricing mechanisms; plumbing device distribution; code changes; sprinkling restrictions; leak detection and repair, 1976 - present. 1978 Report indicated a 15% overall use reduction.
California drought experience	-	Several counties participating reported various programs and results. Teknekron, Inc., Urban Drought in the San Francisco Bay Area: A Study of Institutional and Social Resiliency, Funded by a grant from the National Scence foundation's Directorate for Applied Science and Research Applications, has analyzed the experience and this will be a valuable source.
Washington Suburban Sanitary Commission	-	Public education; distribution of devices; pricing; plumbing code changes; leak detection and repair, 1973 - present.

Results of these programs reported in the literature will be analyzed and updated through telephone interviews.

Local Programs -- Massachusetts Communities

Calls are being made to several Massachusetts communites which were reported by NERBC and others to have conservation programs. In general, it appears that the most successful reported programs in this area are those which attribute their demand reduction to leakage detection and repair rather than the demand management techniques described above.

Communities with programs where results can be documented and measured will be recontacted for further analysis of their experience. The following is a list of communities contacted and programs identified. Also included are several still to be contacted.

Community	Program
Town of Amherst, Mass. Interview 4/30/80 Peter Westover Conservation Officer	- 1974-5 "NOVA" Showerhead Program in U. Mass. Dormitories - 1978 Drought Restrictions - Proposed Public Education program demonstration grant from Mass. Division of Water Pollution Control will go into effect June, 1980.

Other Sources: H. Vanderleeden, Memorandum to Robert L. Cranbell re: Water Savings "NOVA" Showerhead, March, 1975.

Town of Arlington Interview with John E.Bowler, Dept. of Public Works 5/12/80	- 25% Reduction in usage since 1972 entirely attributable to annual leakage detection and repair program. - Planning a public educational program for schools, occasional promotional brochures in annual bill mailings.

Other Sources: Raymond A. Ouellette, Director of Public Works, letter and summary of leakage control program to Andrea Larson, Mass. Department of Environmental Affairs, April 5, 1979.

Pipeline Testing Service, Report of Leakage Survey on Domestic Distribution System, Arlington, Massachusetts, February 28, 1979.

Community	Program
Town of Burlington, Massachusetts Telephone interview Harold J. Publicover, Superintendent 4/30/80	- Public Education Program consisted of one AWWA bill inser - 25% reduction entirely due to leakage survey and repair.

Other Sources: Pipe Line Testing Service, Water Leakage Survey, for Town of Burlington, Mass., on January 7, 1980.

Town of Cohasset	- To be contacted
Town of Holden, Mass. Telephone Interview with Mr. William Oliver, Dir. Dept. of Public Works 5/1/80	- Change in Rules and Regulations to require pressure reducing valves and water saving fixtures on all new construction and renovations - took effect July 1979 - Public education - water bill inserts.
Town of Ipswich, Mass. Interview with James E. Chase, Water/Sewer Mgr. 4/8/80	- Public education program by League of Women Voters (to be contacted) - 1978 price increase ca. 45% - Reductions in total consumption attributable to leakage detection and repair.

1977 = 1.1 mgd
1978 = 1.0 mgd
1979 = .9 mgd

Other Sources: Regulations of the Town of Ipswich Water Div., 1978.

Community	Program
Lynnfield Center Water District	- Public Education; - Sales of water saving devices; - Changes in rate structure to increasing block; and - Leak detection and repair.

Sources: Case Study from: Walter Newman, "Municipal Officials Guide to Water Conservation," New England Interstate Water Pollution Control Commission, Water Conservation Project, Draft, 1/14/80.

Victor D. Christina, Chairman, Water Commissioners, 1978, mimeographed report.

Town of Melrose, Mass.	- 1978 increasing block rate price structure was implemented - effected a per capita reduction of 10 gpd.

Other Sources: To be reviewed: Metcalf & Eddy, Rate Study for Town of Melrose, 3/11/77.

Town of Natick Mass. Interview with James Spiller, Water & Sewer Supervisor, 5/8/80	- Billing inserts for public education. - Town meeting passed local regulations requiring water saving devices in new construction and renovations
Northboro, Mass. Interview with Alfred Stone, Sr., Water & Sewer Superintendent, 5/8/80	- No conservation plans reported.

Town of Stoughton, Mass.	- To be contacted. - NERBC Survey reports use restrictions; pricing techniques; and leak detection and repair program.

PPENDIX A: WATER RATES CHARGED BY MDC*

Communities in District -- Rate $240.00 Per Million Gallons

Arlington	Lynnfield Water Dist.	Newton	*Wakefield
Belmont	Malden	Norwood	Waltham
Boston	Marblehead	*Peabody	Watertown
Brookline	Medford	Quincy	*Weston
*Cambridge	Melrose	Revere	*Winchester
*Canton	Milton	Saugus	Winthrop
Chelsea	Nahant	Somerville	
Everett	*Needhan	Stoneham	
Lexington		Swampscott	

*Partially Supplied Members

1/3 usage clause	30% usage clause	No Min. clause
Canton Weston	Needham	Cambridge
Wakefield Winchester		Peabody

Non-Members outside of District who pay only for actual consumption

City or Town	Rate	City or Town	Rate
Chicopee	$40.90	Northborough	$240.00
Framingham	195.00	South Hadley	
Marlborough	195.00	Fire Dist. #1	54.50
		Wilbraham	57.50
		Worcester	240.00

Special agreements for Non-Members outside Dist.

	Rate	Remarks
Clinton	$240.00 per M.G.	In excess of 800 M.G. per year free
Leominster	$100.00 per M.G.	Min. rate of 1 M.G. per day.
Southboro	$195.00 per M.G.	150,000 gals. per day free.

Special agreements

	Rate	Remarks
Lynn - (non-member) (Water used by the General Electric plant.)	$240.00 per M.G.	Pays for actual consumption

Agency's		Rate
M.D.C. Parks and 4 swimming pools		$240.00 per M.G.
M.D.C. Sewerage Division	Chelsea Creek Cambridge	$240.00 per M.G.
General Services Administration	Waltham	$240.00 per M.G.
Westboro State Hosp.		$240.00 per M.G.
State Institutions	Walter E. Fernald School and the Metropolitan State Hospital	$240.00 per M.G.

* Table from MDC Water Division Statistical Section

APPENDIX B

Rates Charged for Metered Water by Cities and Towns in the Metroplolitan Water District*

July 31, 1979

			Rate per 100 cu. ft.
	ARLINGTON (1/1/75)		
Quarterly:	1,000 cu. ft. max. quantity for min. rate.	$ 6.50	
	Over 1,000 cu. ft.		$ .65
	BELMONT (7/1/79)		
Quarterly:	800 cu. ft. max. quantity for min. rate	$ 6.50	
	Over 800 cu. ft.		.55
	BOSTON (1/1/78)		
Quarterly:	No minimum charge, all quantities		.89
	BROOKLINE (4/1/79)		
Quarterly:	No minimum charge, all quantities		.65
	CAMBRIDGE (1/1/76)		
Semi-annually:	2,700 cu. ft. max. quantity for min. rate	$10.00	
	Over 2,700 cu. ft.		.36
	CANTON (1973)		
Semi-annually:	2,000 cu. t. max. quantity for min. rate.	$ 9.00	
	Over 2,000 cu. ft.		.45
	CHELSEA (4/1/74)		
Quarterly:	1,000 cu. ft. max. quantity for min. rate	$ 5.50	
	Over 1,000 cu. t.		.55
	EVERETT (10/1/73)		
Quarterly:	2,000 cu. ft. max. quantity for min. rate	$ 8.00	
	Over 2,000 cu. ft.		.40
	LEXINGTON (1/1/74)		
Semi-annually:	2,500 cu. ft. max. quantity for min. rate	$11.25	
	Over 2,500 cu. ft.		.45
	LYNNFIELD WATER DISTRICT (3/1/75)		
Semi-annually:	2,000 cu. ft. max. quantity for min. rate	$19.00	
	Over 2,000 cu. ft.		.70
Quarterly:	Business Rates		
	1,000 cu. ft. max quantity for min. rate.	$ 9.50	
	Over 1,000 cu. ft.		.70

MALDEN (1/1/79)

Semi-annually:	2,500 cu. ft. max. quantity for min. rate	$12.50	
	Over 5,000 cu. ft.		.50

MARBLEHEAD (1/1/80)

Semi-annually:	2,000 cu. ft. max. quantity for min. rate	$15.00	
	Over 2,000 cu. ft.		.75

MEDFORD (1/1/75)

Semi-annually:	1,800 cu. ft. max. quantity for min. rate	$ 9.00	
	Over minimum charge		.50

MELROSE (7/1/79)

Annually:	Minimum charge 6 months	$16.25	
	First 5,000 cu. ft.		.65
	5,000 to 9,999 cu. ft.		.75
	10,000 to 14,999 cu. ft.		.85
	Over 15,000 cu. ft.		.90
	Minimum charge less than 6 months	$ 3.00 per month	

MILTON (7/1/78)

Semi-annually:	1,600 cu. ft. max. quantity for min. rate	$12.00	
	Over 1,600 cu. ft.		.75

NAHANT (1972)

Annually:	4,000 cu. ft. max. quantity for min. rate	$20.00	
	Over 4,000 cu. ft.		.50

NEEDHAM (7/1/75)

Semi-annually:	2,000 cu. ft. max. quantity for min. rate	$13.50	
	Over 2,000 cu. ft.		.675

NEWTON (3/6/74)

Semi-annually:	Meter size	Rate	Cu. Ft. allowed
	5/8"	$ 9.00	2,000
	3/4"	9.00	2,000
	1"	13.50	3,000
	1-1/4"	22.50	5,000
	1-1/2"	22.50	5,000
	2"	31.50	7,000
	3"	45.00	10,000
	4"	58.50	13,000
	6"	76.50	17,000
	8"	99.00	22,000

In excess of cu. ft. allowed	.45

Big concerns and schools

Averaging daily for period for which bill is rendered:

Under 1,000 cu. ft. per day - rate per 100 cu. ft.	.45
Over 1,000 cu. ft. per day	.38

NORWOOD (6/30/74)

uarterly:	1,000 cu. ft. max. quantity for min. rate	$ 5.25	
	Up to 10,000 cu. ft.		.525
	10,000 to 90,000		.375
	Over 90,000 cu. ft.		.285
onthly:	Factory rates		
	Up to 3,333 cu. ft.		.525
	3,333 - 30,000 cu. ft.		.375
	30,000 - 100,000 cu. ft.		.285
	Over 100,000 cu. ft.		.240

PEABODY (9/22/76)

uarterly:	No minimum charge, all quantities		.40

QUINCY (1/1/74)

emi-annually:	2,000 cu. ft. max. quantity for min. rate	$12.00	
Domestic	Over 2,000 cu. ft.		.60
Industrial-	Use, up to 29,900 cu. ft.		.60
	Over 30,000 cu. ft.		.55
	Summer season, Min. rate	$36.00	
	Over Minimum rate		.60

REVERE (10/1/74)

uarterly:	1,667 cu. ft. max. quantity for min. rate	$10.84	
	Over 1,667 cu. ft.		.65

SAUGUS (4/1/69)

emi-annually	3,000 cu. ft. max. quantity for min. rate	$12.00	
	Over 3,000 cu. ft.		.40

SOMERVILLE (2/1/74)

emi-annually:	2,000 cu. ft. max. quantity for min. rate	$ 9.60	
	Up to 300,000 cu. ft.) If commercial accounts,		.48
	300,001 to 600,000) bills rendered monthly		.40
	Over 600,000 cu. ft.		.35

STONEHAM (7/1/74)

emi-annually:	2,100 cu. ft. max. quantity for min. rate	$10.50	
	Over 2,100 cu. ft.		.45

SWAMPSCOTT (7/1/75)

nnually:	4,000 cu. ft. max. quantity for min. rate	$22.00	
	Over 4,000 cu. ft.		.55

WAKEFIELD (7/1/74)

emi-annually:	1,500 cu. ft. max. quantity for min. rate	$12.50	
	1,500 to 100,000 cu. ft.		.60
	Over 100,000 cu. ft.		.40

WALTHAM (7/1/74)

Monthly:	Up to 50,000 cu. ft.		.55
	50,000 to 2,000,000		.45
	Over 2,000,000		.40
Quarterly:	Meter Size	Cubic Feet	Minimum Charge
	5/8"	1,500	$ 8.25
	3/4"	2,200	12.00
	1"	3,800	21.00
	1-1/2"	7,600	42.00
	2"	12,000	66.00
	3"	24,000	132.00
	4"	38,200	210.00
	6"	76,400	420.00
	8"	120,000	660.00
	10"	233,300	1,200.00

Over maximum quantity for minimum rate -- $.55 per 100 cu. ft.

WATERTOWN (7/1/75)

Semi-annually:	2,500 cu. ft. max. quantity for min. rate.	$16.00
	Over 2,500 cu. ft.	.64

WESTON (1973)

Semi-annually:	2,000 cu. ft. max. quantity for min. rate	$10.00
	Over 2,000 cu. ft.	.57

WINCHESTER (9/15/70)

Semi-annually:	1,430 cu. ft. max. quantity for min. rate	$ 6.00
	All Quantities	.42

WINTHROP (1/1/76)

Annually:	6,667 cu. ft. max. quantity for min. rate	$40.00
	Over 6,667 cu. ft.	.60
	Summer Session:	
	5,000 cu. ft. max. quantity for min. rate	$30.00
	Over 5,000 cu. ft.	.60

WOBURN (1979)

Semi-annually:	Flat rate, no quantities $13.00 per Family unit.	
	Industrial Commercial	
	All quantities	.50

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* Table from MDC Water Division Statistical section.

PPENDIX C: RATES CHARGED FOR METERED WATER BY CITIES AND TOWNS SUPPLIED BY THE METROPOLITAN WATER WORKS OUTSIDE OF DISTRICT *

			Rate per 100 Cu. Ft.
	CHICOPEE		
onthly:	$120.00 per Million Gallons for Westover Field		
uarterly:	Residential Rates		
	1,000 cu. ft. Max. Quantity for Min. Rate	$3.40	
	1,000 cu. ft. - 10,000 cu. ft.		.34
	10,000 cu. ft. - 50,000 cu. ft.		.28
	Industrial Rates		
	50,000 - 100,000		.25
	100,000 - 500,000		.22
	500,000 - 2,500,000		.145(sic)
	2,500,000 - 9,000,000		.11
	Over 9,000,000		.07
	CLINTON		
uarterly:	2,500 cu. ft. Max. Quantity for Min. Rate	$7.50	
	Over 2,500 cu. ft.		.30
	FRAMINGHAM		
very our Months	No Minimum Charge all quantities		.40
	LEOMINSTER		
uarterly:	First 900 cu. ft.		.40
	900 cu. ft. - 9,000 cu. ft.		.30
	Over 9,000 cu. ft.		.20
	LYNN		
emi-Annually:	2,000 cu. ft. Max. Quantity for Min. Rate	$12.00	
	Over 2,000 cu. ft.		.60
	Industrial Rates		
	First 100,000 cu. ft.		.60
	100,000 - 2,400,000 cu. ft.		.48
	Over 2,500,000 cu. ft.		.32
	MARLBORO		
uarterly:	First 5,000 cu. ft.		.50
	5,000 - 10,000 cu. ft.		.40
	10,000 - 15,000 cu. ft.		.30
	Over 15,000 cu. ft.		.20

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Comments on Draft Technical Memorandum

The page numbers referred to below are all page numbers in this report, not in the draft report.

1) Q: Page 3 - it would be helpful for the reader to know exactly which "other technical memoranda" are referred to, as well as page numbers for such cross references. (NCAC - 6/4/80)

A: Explanation made through Change in text, p. 3.

2) Q: Page 6 - in considering conservation strategies, the "legal and institutional constraints under which the MDC operates" should be spelled out. (NCAC 6/4/80)

Q: Page 8 - MDC's "legal and institutional options and constraints should be clearly explained, and the entire paragraph should be greatly expanded. (NCAC 6/4/80).

A: The question of institutional and legal contraints has emerged as an issue for this alternative during the review of the draft memoranda. In some cases, the "constraint" is actually the description of the problem to be addressed through conservation, e.g., a peak or long-term supply problem. Defining these situations and the conservation measures which might be useful in addressing them is part of the Phase II analysis.

The legal and institutional structure under which the MDC operates as a water wholesaler must also be taken into account in some way. For example, in assessing the impact of pricing strategies, it appears that two steps must be taken -- one to identify the changes in user community rate structures which might reduce consumption and then the changes in either MDC's wholesale prices or the method by which MDC reviews local rates which would implement the changes at the consumer level.

Further, the authority to implement the conservation measures must be considered because implementation is part of the impact assessment. In devising conservation scenarios for assessment, authority for implementation of some techniques exist now - for others the authority does not.

1. Supply improvement techniques --

It may be assumed that the MDC for its own system and the local user communities for theirs, have the authority to repair leakage or improve metering. The questions are: how much water is lost to leakage; how much can be detected; how much can reasonably be recovered over time -- given the economics and disruption impacts.

If this is a reasonable alternative, then how to implement a program is a question that might be addressed later in Phase II.

Under the present system, the authority for setting rate structures in order to achieve conservation or issuing certain regulations for purposes of demand management may not be assumed and these aspects must be considered. Mechanisms for their implementation -- given the present structure -- would be part of the analysis and design if this is to be a selected alternative.

3) Q: Page 6 - what might "an Education Program directed at residential user habit changes" include? How would such a program be implemented? (NCAC 6/4/80)

Q: Page 12 - last paragraph - what kind of "educational campaign directed solely at changing water using habits" is envisioned? Would this be multi-media campaign, using the Press, TV, and radio? (NCAC 6/4/80)

A: The specifics of the conservation programs to be assessed will be developed during the Phase II work.

4) Q: Page 11 - Table on Residential Use Assessment - the types of information to be gained from the Demand/Use task should be elaborated. (NCAC 6/4/80)

Q: Page 11 - Table on Residential Use Assessment - the kind of information to be derived from the Demand/Use task should be elaborated. (NCAC 6/4/80)

A: In both cases, the amount of household use in the study area is needed from the Demand/Use Research as specified in the Table. In order to assess the impact of plumbing codes applicable only to new construction and renovations, the rate of new unit construction must also be identified.

5) Q: Page 11 - Table on Residential Assessment - in analyzing "Present Outside Residential Usage" will any consideration be given to the use of drought-resistant plants in residential landscaping? (NCAC 6/4/8)

A: Information specifying amounts of reduced consumption from the use of such plants has not been identified. Encouraging their use might be part of an educational program. An effort will be made to consider this as part of a scenario to reduce long-term demand.

6) Q: Page 14 - has the experience in water conservation of Raytheon Corp., been investigated? (NCAC 6/4/80)

A: Raytheon has been identified as a source and their experience will be used in Phase II as part of the development of an industrial conservation program.

7) Q: NCAC would like a copy of Michael Gravitz's report to Andrea Larson entitled, "A Water Conservation Plan for the MDC". (NCAC 6/4/80)

A: Requests for this report should be addressed to the MDC.

8) Q: Was any of the information from Denver's Water Department useful in preparing this memorandum? (NCAC 6/4/80)

A: Yes, but the information available on Denver's program is contradictory and direct contact will have to be made in order to better define and analyze their program.

9) Q: What is the impact of potential engery savings on the assessment of the conservation alternative? (NCAC Workshop 6/6/80)

A: The question of energy costs and savings through conservation comes up in two ways: first, the potential savings to individual consumers from reducing hot water use and second, the potential energy savings to the utility of pumping and treating less water either under the present system or given a new engineering alternative. An effort will be made to assess the potential of the motivation for consumer savings as part of the conservation alternative. The energy costs for pumping and treatment will be part of the engineering evaluation of alternatives.

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DRAFT TECHNICAL MEMORANDUM

PRELIMINARY EVALUATION OF LEAKAGE AND UNMETERED WATER

Northfield Environmental Impact Study-Phase I: Basic Services

Prepared by

Bechtel Incorporated

13323-100

SUMMARY

LEAKAGE AND UNMETERED WATER

Unaccounted-for water is usually defined as the difference between the amount of water purchased (or produced) by a municipality and the sum of water recorded on consumer meters.

The components of unaccounted-for water include: water lost through distribution system leaks and breaks (leakage); inaccurate metering; unmetered use (The terms unmetered and unaccounted for water are used interchangeably. In this study, however, unmetered will refer to that category of unaccounted-for water which is used in services which are not metered.); public use for municipal buildings and pools, fire-fighting, street cleaning, and sewer flushing; and unauthorized connections.

This study is a preliminary review of existing estimates of unaccounted-for water and leakage with recommendations for refining these estimates and order-of-magnitude cost estimates of leak detection and repair.

No new data on unaccounted-for water categories or leakage is compiled in this study. Instead, the methodology and estimates developed in previous studies for the MDC are reviewed and evaluated. A sensitivity analysis is made on estimates of water use developed for 21 fully-supplied water district member communities from a 1980 study. The data from these 21 communities comprised 88.8% of the MDC annual water deliveries. For this analysis, ranges of confidence in the data were developed to test the sensitivity of the 1980 study results to potential errors. The analysis provides a range of probable potentially recoverable leakage around the estimate deduced in the 1980 study.

The results of the analysis indicate that potentially recoverable leakage in the distribution systems of MDC user communities is probably between 6% and 27% of the deliveries to these municipalities. While this analysis only tests the sensitivity of the 1980 computations to potential errors in the data, the results suggest that significant potentially recoverable leakage exists and should be studied in more detail in future phases. Other categories of unaccounted-for water were reviewed but no total estimated range was evaluated at this time.

A separate evaluation is made of methods currently used to estimate leakage in the MDC transmission and distribution system. A sensitivity analysis of the computation of unaccounted-for water in the MDC distribution system east of Weston and Norumbega Reservoirs was performed and the computation was found to provide a reasonable estimate of leakage in that portion of the system. However, the

computation only applies to a portion of the MDC system and no estimate could be developed for total leakage. Additional studies are required.

Some amount of leakage is unavoidable in any system. The amount depends on factors such as the age of the system, chemical characteristics of the water, the nature of the soil, the pipeline materials, and the climate. No precise relationship between these variables and amounts of leakage has been established. Instead a formula for unavoidable leakage cited in the engineering literature (250 gallons/mile/day/inch diameter of pipe) is used to separate a level of background leakage from the amount which may be potentially recoverable.

How much of the potentially recoverable leakage can be actually recovered depends on the size and location of the leaks, whether the leaks are detectable, the frequency of leakage detection surveys, and the funds available to the communities for leakage detection and repair.

Information on these factors is not available short of conducting actual community leak detection and repair programs. Instead, a calculation of the costs of repairing a "typical size" leak was made. This was used to estimate order-of-magnitude direct costs to detect and repair potentially recoverable leakage.

A comparison of the direct costs to locate and repair a "typical" leak and the assumed value of water formulated in the study suggests it is economical to repair any leak greater than 0.8 gallons per minute. Since existing leak detection equipment can detect leaks as small as 1-5 gpm, it appears that if a leak is detectable, it is normally economical to repair.

However, it is important to recognize that this order-of-magnitude estimate of detection and direct repair costs is not an actual program cost and is not applicable to all locations where leakage may appear. Nor is information yet available to determine how long it would take to repair all the potentially recoverable leakage. (Only a limited amount of any distribution system can be surveyed and repaired in any year.) In addition, the administration, traffic control and disruption costs of such a program need to be factored into the overall repair costs for each community.

Furthermore, leakage is a continuous problem: more leakage occurs as some is being repaired. Additional studies are needed to estimate the amount of leakage which continues to occur between repairs and must be accommodated in water supply planning.

A list of recommended studies is included for improving the range of estimates of potentially recoverable leakage and the associated costs of detection and repair. These studies primarily focus on:

- Refining data on unaccounted-for water, leakage, and detection and repair costs;
- Developing estimates of leakage and costs of a repair program; and,
- Evaluating additional methods to develop or confirm leakage estimates.

INTRODUCTION

In recent years, increasing attention has been focused on unaccounted-for water in the Metropolitan District Commission (MDC) and user community water distribution systems. While there is no commonly-accepted definition of unaccounted-for water, it is most frequently defined as the difference between the amount of water purchased (or produced) by a community and the sum of the amounts recorded by consumer meters.

Regardless of the definition adopted, the term unaccounted-for water is frequently misinterpreted to mean water lost through leakage. Although leakage can be a major element of unaccounted-for water it is by no means the only component. In any community, unaccounted-for water normally will consist of the following components:

- Inaccurate meters - both master meters and consumer meters;

  Older meters commonly "slip" or underregister. Also, they may not register very low flows. This means that water is being used but not recorded.

- Unmetered residential, commercial and industrial uses;

- Public water uses such as fire fighting, street cleaning and sewer flushing, watering of public lawns and gardens, pipeline flushing ("blow-offs"), public buildings and swimming pools;

- Unauthorized connections and hydrant openings;

- Unavoidable leakage - that level of background leakage that cannot be eliminated. The amount depends upon factors such as the system's age, chemical characteristics of the water, the nature of the soil surrounding the pipes, pipeline materials, and the climate;

- Potentially recoverable leakage - leakage that is potentially capable of being detected and repaired. The amount varies with the system and its characteristics.

Quantifying the components of unaccounted-for water in order to estimate how much is potentially recoverable leakage in a water distribution system is a deductive analysis which involves the following steps:

- The first step is to estabish total volume of water purchased (or produced) during a given time period. In the MDC water user municipalities this is the annual volume of water sold by the MDC to the municipality as recorded on revenue meters. In the MDC transmission and distribution system it is the total amount produced.

- From this value all metered uses of water are deducted. The result is "unaccounted-for water".

- In order to further analyze how much of that unaccounted-for water is actually used but not metered, estimates are then made for meter slippage, unavoidable leakage and unmetered flows.

- After these deductions are made, the balance is theoretically, potentially recoverable leakage. However, the results of such an analysis are only as reliable as the input data which have varying degrees of reliability and depend on: the accuracy of flow meters, the validity of data on actual consumption furnished by the communities, and the accuracy of assumptions concerning meter slippage, unmetered use, and unavoidable leakage.

The purpose of this study is to review existing data and studies of the MDC and user community distribution systems pertaining to unaccounted-for water and then develop preliminary estimates of:

- The proportion of unaccounted-for water which is leakage;

- The amount of leakage which is unavoidable;

- The amount of leakage that is potentially recoverable;

- Order-of-magnitude costs to locate and repair the recoverable leakage.

Leakage can potentially occur anywhere in the approximately 5000 miles of distribution pipelines and tens of thousands of valves, connections, and hydrants in the MDC user communities. Most often, the leakage will occur underground and be difficult to detect. In addition, unknown deliveries and data errors inherent in these systems make precise predictions of the amount of leakage and the associated repair costs extremely difficult if not impossible to calculate. Therefore, leakage and associated costs can only be estimated. These estimates will have a range of accuracy depending upon the confidence placed in the data. This study is a preliminary effort at establishing a range of leakage and associated costs. Additional studies are needed to refine and narrow the range of the estimates.

The purpose of these preliminary estimates is to assist in evaluating a program of leakage detection and repair as a part of the conservation alternative in comparison to other alternatives available to the MDC for augmenting supplies.

The second primary objective of this analysis is to outline future studies necessary to refine the estimates of recoverable leakage and associated repair costs.

The principal information-gathering techniques employed were a literature search of technical publications, review of previous reports and raw data provided by the MDC, and personal interviews with MDC staff and water agency officials from Boston and two other MDC member communities. (Interviews were conducted with officials in Waltham and Somerville. Waltham was selected because its proportions of commercial, industrial, and residential consumption were similar to those of the MDC user communities as a whole. Other considerations were its high ratio of metered-to-unmetered services and its size. It is one of the larger MDC municipalities. Somerville was chosen because it is also a relatively large water user, and its ratio of metered-to-unmetered services is relatively low).

The methodologies used to estimate the extent of leakage and repair costs are relatively unsophisticated and employ professional judgement in addition to a statistical approach. These approaches are consistent with the available data and the scope and intent of this phase of the EIR study. The estimates developed in this study are intended to provide preliminary order-of-magnitude values which will be refined in future phases of the EIR.

LEAKAGE IN COMMUNITY DISTRIBUTION SYSTEMS

Previous Studies

Two studies commissioned by the MDC within the past ten years have analyzed the problem of leakage and unmetered water within the member community distribution systems. The first was the "Water Usage Study in Communities Served by the Metropolitan District Commission." (Water Resources Research Center, 1975) frequently referred to as "The Curran Report". The other was a memorandum entitled "Water Conservation, Recommendations for the Metropolitan District Commission" (Linsky, January 1980). Both studies had a wider focus than just the subject of leakage and unmetered water. However, this subject received significant attention in each study.

The scope of The Curran Report provided for "A study of a water conservation program to encourage better water management among users of the Metropolitan District Commission water system". The study assembled and summarized a great deal of data concerning MDC user communities, including flow data on each community with respect to total flow, domestic, public, commercial, industrial, and unmetered water. Sub-categories of unmetered water were estimated for each community. The report suggested that a very substantial portion (more than 70 mgd) of MDC's total flow was lost in distribution system leaks and breaks. This report was an initial effort to estimate water usage and by its own evaluation had a greater level of confidence in some data than in others. The leakage figure was qualified by the authors as potentially subject to error since they questioned the validity of some of the data available to them in making the estimates.

The 1980 "Recommended Water Conservation Program" prescribed water conservation strategies for the MDC and water-user communities. It recommended that programs which could be implemented by the MDC and the user municipalities should be given priority in a conservation program. Estimates of potentially recoverable leakage were made in order to determine the communities having potentially recoverable leakage. Estimates of this category were made through the compilation of "Flow Profiles" for each of 21 fully supplied member communities for which data was available. (The Flow Profiles themselves were compiled by Thomas Gawrys in the Statistical Section of the MDC Water Division. Future references to "The MDC Study" refer to this 1980 "Recommended Water Conservation Program.") The flow profiles placed values on each category of water usage. Where the value of a usage category was unknown, it was estimated from the best available information.

Although different methodologies were used, values of potentially recoverable leakage found in The MDC Study were not far different than those found the in The Curran Report. The MDC Study added more information about meter slippage from user communities' maintenance programs and therefore

concluded that a larger amount of unaccounted-for water was probably used and not recorded rather than lost through leakage. The findings of The Curran Report and The MDC Study concerning unaccounted for water are summarized in Table 1.

These two studies developed useful information concerning the problem of leakage and unmetered water within the user communities.

In order to evaluate the range of potential accuracy of these previous estimates of the amount of potentially recoverable leakage within the MDC water user communities, this study will focus on the data used in the Flow Profiles prepared by the MDC Water Division Statistical Section for 21 fully-supplied member communities as reported in The MDC Study. This focus will be directed to formulating a level of confidence in the data used and the sensitivity of the results to potential errors in the data.

TABLE 1:

Summary of "The MDC Study" and "The Curran Report" Estimates of Categories of Unaccounted-for Water

ESTIMATES OF UNACCOUNTED FOR WATER

Category	Percent of Total Supply	
	Curran Report[1]	MDC Study[2]
Meter Slippage	3.0%	6.2%
Unmetered Public Use	4.5%	7.2%
Unmetered Domestic, Commercial, Industrial, and Institutional	4.0%	4.6%
Unavoidable Leakage	4.0%	3.0%
Potentially Recoverable Leakage	22.5%	18.3%
Totals	38.0%	39.3%

1 Water Resources Research Center, 1975

2 Linsky, 1980

Methodology of the MDC Study

For this study, the MDC Water Division Statistical Section compiled flow profiles of water usage in 21 of the fully-supplied communities. The methodology is as follows: various categories of known or estimated usage were listed and subtracted from the 1978 daily per capita consumption leaving as a remainder the potentially recoverable leakage. All categories were reported in gallons per capita per day (gpcd). Information for each communitiy was taken from the 1978 Water Services and Metering Report, a report compiled annually for the MDC by each water user community showing the flow for various categories of water use. (As an example, Waltham's 1978 Water Services and Metering Report is contained in the Appendix to illustrate the type of information reported to the MDC). The flow profile for Waltham is shown in Table 2 as an example.

Sources of information for each category of usage in the flow profile are as follows:

1978 Total: Consumption as recorded by MDC revenue meters (MDC meters used to measure flow to water user communities) for the 1978 calendar year divided by the population of the community from the 1975 state census.

Domestic: Actual domestic consumption as reported to the MDC by the community in its 1978 Water Services and Metering Report.

Also The MDC Study developed a correlation between per capita domestic consumption and the percentage of single family homes in the community. The graph on page A-9 of the Appendix illustrates the correlation. Therefore, in cases where no estimate of domestic consumption was reported by the community, an estimate was made by the Statistical Section based on domestic per capita usage in a community with similar housing characteristics.

Domestic Meter Slippage: Because of their nature as mechanical devices with moving parts, water meters begin to lose accuracy soon after they are installed. The loss, which is always under-registration, is imperceptible at first, but becomes progressively significant each year the meter is in service. Loss was computed on the basis of 1 percent meter slippage per year of average age of meters, not exceeding 10 percent. In order to enable MDC to estimate a value, each community provided the MDC with a description of its meter replacement program. The average age of meters was taken to be one half of the replacement period. For example, if a community replaces ten percent of its meters per year, all meters will have been replaced after ten years. After ten years, some meters will be ten years old, some will be new, however, the mean age will be approximately five years.

TABLE 2[1]

FLOW PROFILE

City or Town: WALTHAM

Population: 56,700

ALL FIGURES ARE GALLONS PER CAPITA PER DAY

1.	1978 TOTAL	204	Minimum Flow	135
2.	Less Domestic	78	Less 30% of 2.	25
		126		110
3.	Less Domestic Meter Slippage[2]	4		
		122		
4.	Less Commercial & Industrial & Institutional	83		
		39		
5.	Less Commercial & Industrial & Institutional Meter Slippage	4		
		35	Less 90% of 4. and 6.	80
				30
6.	Less Non-Revenue Unmetered[2]	5		
		30		
7.	Less Unavoidable Leakage[2]	6	Less 7.	6
8.	Potentially Recoverable Leakage[2]	24		24

POTENTIALLY RECOVERABLE LEAKAGE: 12%

[1] This table is reproduced from: H.S. Linsky, "Water Conservation: Recommendations for the Metropolitan District Commission," January, 1980.

[2] Indicates categories that are elements of unaccounted-for water

<u>Commercial, Industrial and Institutional</u>: As actually reported by the community. In cases where data were combined with domestic consumption in community reports this category became the net after subtracting domestic consumption.

<u>Commercial, Industrial, and Institutional Meter Slippage</u>: Loss was computed on the basis of one percent meter slippage per year. Average age of meters was computed as explained under "Domestic Meter Slippage".

<u>Non-Revenue Unmetered</u>: As reported by communities to the MDC in their annual reports. Where information was missing, an estimate was made based on a community with similar characteristics.

<u>Unavoidable leakage</u>: Based on a formula of 250 gallons per day per inch diameter per mile of pipe. This value was calculated from information on the user community distribution systems length and diameter of mains supplied by those communities to the MDC.

<u>Potentially Recoverable Leakage</u>: The net result after the previously listed usage categories were subtracted from the 1978 total consumption.

As a rough check, a parallel analysis was also performed (refer to right-hand side of the sample Flow Profile sheet). This analysis began with the potentially recoverable leakage as described above. The potentially recoverable leakage was subtracted from the minimum metered flow (as recorded on MDC Revenue Meters--usually about 3 A.M.). The remainder was then proportioned to domestic, commercial, industrial, institutional, and non-revenue unmetered night-time uses and unavoidable leakage. The percent of night-time use in the domestic and non-domestic categories was then compared with known characteristics of the community (particularly concentrations of industry and commerce) to determine if it appeared reasonable.

These Flow Profiles provided a useful means of developing preliminary estimates of potentially recoverable leakage in each community. However, the results are only as accurate as the estimate of usage categories which went into the analysis. Various degrees of confidence can be placed on each category of input data. For example, as previously mentioned, variation among per capita domestic consumption by community is small, once the effect of the type of housing is determined. Hence, a relatively high degree of confidence can be placed on the values for this usage category.

However, the same degree of confidence cannot be placed on the category of commercial, industrial and institutional consumption, because of unauthorized connections into fire lines, differences in the way each community defines these categories and potential underestimation of the flows to unmetered buildings.

The anlaysis performed in this study will assign ranges of confidence to each of the usage categories estimated in Th MDC Study. In order to assist in estimating these ranges (confidence, interviews were conducted with the head of the MDC Water Division Statistical Section, the Water Commissioner of Somerville, the Director of Public Works f(Waltham, and the Chief Design Engineer for the Boston Wate and Sewer Commission.

Ranges of Confidence in Usage Categories

Given the interview information, data gathered from technical journals and engineering judgement, ranges of confidence in the estimates of each usage category were developed for each community. The rationale behind the range for each usage category is as follows:

1978 Total: Was assumed to be correct. A recent study concluded that 90-95 percent of flow to MDC member communities was being accurately measured and recorded. (Telemetry Systems Engineering, Inc., 1978) The revenue meters showed some inaccuracies; some overregistering, others underregistering. Therefore, while the per capita flow to an individual community may have intermittent errors, the aggregate flow to all communities would result in a counterbalancing of errors. Moreover, because of the economic importance of revenue meter readings, any readings significantly different from previous periods are soon noticed and corrected.

Domestic: The percentage of single-family homes has a definite effect on per capita domestic consumption in a community. Once this effect is accounted for, 90 to 95 percent of MDC communities fall within a range of 8 gpc of the mean. (Page A-9 of the Appendix shows a graph of pe capita domestic consumption versus percent single family homes. Each data point corresponds to an MDC member community. A good correlation is noted. Upper and lower parallel lines on the graph encompass 95 percent of the dat points. These lines are 8 gpcd above and 8 gpcd below separated by 16 gcpd). Therefore, a range of 16 gcpd was established symmetrically about the mean.

Domestic Meter Slippage: MDC estimates are based upon mete replacement programs within each community. The specific formula employed is 1 percent loss in accuracy for each yea of age. This formula is considered a reasonable average estimate. To test for the effect of possible errors, a range of $\pm$ 10% of the MDC estimate was assumed.

Commercial, Industrial and Institutional: This category of use is judged to have a high potential for error. Although 97 percent of services in the MDC user communities are metered, most of the unmetered services are institutions such as churches and schools. Flows to the unmetered users are estimated by the communities. Moreover, there appears

to be some differences among communities in reporting commercial use. What some communities consider commercial, other communities may consider industrial. It is assumed that there may be inherent bias in estimates of unmetered flow which result in these estimates being low. A range of 20 percent of the MDC value with 5 percent below and 15 percent above was used.

Commercial, Industrial and Institutional Meter Slippage: Compound meters are most often used to measure these flows. Unless they are frequently serviced, compound meters can become inaccurate. Because they are somewhat more complex than single-stage meters, compound meters can lose accuracy faster. However, because they handle large flow volumes, they tend to be checked and/or replaced with greater frequency than domestic meters. Information on this class of meter slippage is limited to that discussed under domestic meter slippage. Consequently the MDC estimate, based on a loss of 1 percent accuracy per year is assumed to be reasonable. To test for the effect of possible errors in MDC estimates, a range of $\pm$ 10% was assumed.

Non-Revenue Unmetered: Includes water used for fighting fire, pipeline and sewer flushing, street cleaning, and serving some public buildings, parks and swimming pools. Consumption is estimated by the communities probably on the basis of reports from several municipal departments. In general, these estimates would tend to be low because little or no accounting is made of this water at the time of use. Also, estimates of water used to fight fires or water public lawns and gardens tend to be low since amounts of water discharged in a 4 inch fire stream or through a 1 inch irrigation hose are difficult to estimate even by experienced superintendents.

It was assumed that the total range of confidence for this category was 60 percent of the MDC value. Because of the previously mentioned tendency for this estimate to be low, the range of confidence was assumed to be a symmetrical about the MDC value. Ten percent of the 60 percent was assumed below the MDC value and the remaining 50 percent above the MDC value.

Unavoidable Leakage: Based on 250 gpd per mile per inch of pipe diameter (Babbit, 1962). This is a reasonable estimate. It is considered to be technically impossible to reduce leakage below this amount. Although it is a broad average, it is probably the value most commonly-accepted among water works officials. It includes the unavoidable (and impractical-to-repair) small drips. It also takes account of the fact that even with a conscientious leakage repair program, there is always a lag between the time a major leak begins, and the time it is repaired. A range of $\pm$10% was assumed. This category is a small portion of unaccounted-for water, and even large errors in estimating would have little effect on the total percentage of unaccounted-for water.

The ranges of potential errors developed in the above discussion were then applied to the Flow Profiles used in the MDC Study to determine the sensitivity of the MDC results to possible errors in the estimates of usage. Two values are obtained by this analysis: Minimum expected potentially recoverable leakage (Min . PRL) and maximum expected potentially recoverable leakage (Max. PRL). These values represent the values of potentially recoverable leakage that would be obtained if all the errors in the MDC's estimates of usage were either too high or too low respectively.

The probability is small that all the errors would be equal to the maximum of the range assumed and that all would be above or below the estimated value. Accordingly the Min. PRL and Max. PRL, values obtained represent the extremes of the range of potentially recoverable leakage. The probability that either value represents actual potentially recoverable leakage is very small. The actual amount of potentially recoverable leakage is more probably near the mid-point of the two extremes. The range of potential values will be refined in future phases of the EIR.

The results of this analysis are summarized in Table 3. Since negative leakage is unreasonable, negative values were converted to a zero in Table 3.

The 21 communities studied account for 88.8 percent of the flow to MDC fully and partially supplied communities. This analysis indicates that for these 21 communities, the extreme values of potentially recoverable leakage are 14 to 66 million gallons per day (mgd). This range could also be expressed as from 6 to 27 percent of the total water supplied to these communities.

Since detailed "Flow Profiles" were not developed in the MDC Study for the remaining user communities, the range of recoverable leakage developed for the 21 communities (88.8 percent of the flow) will be used to estimate similar values for the remaining District communities in order to estimate the range of potentially-recoverable leakage for the entire District. The other user municipalities were not included in this analysis due to data constraints. They will be included in a future study. This calculation is summarized in Table 4 and suggests that for all MDC-supplied communities in the District, potentially recoverable leakage can reasonably be expected to fall within a range of 16 to 73 mgd. As stated earlier, these are the extreme expectations. The actual value probably falls somewhere within this range. This assumes that distribution system leakage in these 12 additional communities is similar to that in the previously-analyzed 21. However, since the 12 communities comprise a small amount of the total flow, significant departures from the assumed percentage will affect the total range of leakage only to a limited extent.

TABLE 3

POTENTIALLY RECOVERABLE LEAKAGE (PRL)[1]
IN 21 FULLY SUPPLIED MEMBER COMMUNITIES
(88.8 PERCENT OF FLOW)

	PRL MDC Study[2] (gpd)	Estimated Range - PRL Max. PRL (gpd)	Estimated Range - PRL Min. PRL (gpd)
Arlington	301,320	903,960	0*
Belmont	138,300	442,560	0
Boston	30,623,520	41,469,350	9,569,850
Brookline	478,350	1,169,300	0
Chelsea	275,770	601,680	0
Everett	1,191,300	1,786,950	119,130
Malden	502,290	1,060,390	0
Marblehead	194,130	409,830	0
Medford	2,610,100	3,277,800	1,578,200
Melrose	289,890	611,990	0
Milton	299,310	598,620	108,840
Nahant	16,920	54,990	0
Norwood	187,920	595,080	0
Quincy	1,189,370	2,287,250	0
Revere	908,380	1,362,570	330,320
Somerville	2,337,400	3,143,400	1,128,400
Stoneham	431,200	754,600	0
Swampscott	601,860	745,160	415,570
Waltham	1,360,800	2,154,600	0**
Watertown	1,266,720	1,587,520	685,520
Winthrop	549,720	794,040	264,680
Total	45,754,570	65,811,640	14,200,510

* Zeros are shown where negative values of leakage were obtained from the calculation of the Min. PRL for individual communities, since negative leakage in pressure pipelines is meaningless. Although an alternative method would have been to add the negative values algebraically to reflect an average of the actual ranges chosen, the selection of zero seemed more reasonable. The negative values imply that a narrower range for these communities might be more accurate but the impact on the final totals was minor. (Min. PRL would have been 11.1 mgd if negative value were added algebraically).

** The calculations of Min. PRL for Waltham was zero.

[1] Potentially recoverable leakage (PRL) is leakage that is potentially capable of being detected and repaired. It varies greatly with the system and its characteristics.

[2] Linsky 1980

TABLE 4

Estimated Range of Potentially Recoverable Leakage (PRL)
Within all MDC Water District Member Communities
(Does not include flow to Western Communities)

12 MDC Communities Without Flow Profiles	Water Purchased 1979 (Million Gallons)
Cambridge	0
Canton	444.21
Lexington	1935.96
Lynnfield W.D.	154.40
Needham	400.04
Newton	3820.82
Peabody	181.04
Saugus	1471.68
Wakefield	588.38
Weston	381.06
Winchester	377.77
Woburn	192.36
Total	9947.72 = 27.3 MGD average

	Supply	Max. PRL (27.1%)	Min. PRL (5.8%)
	Million Gallons Per Day		
Potentially Recoverable Leakage -Communities with "Flow Profiles" (from Table 3)	242.7	65.8	14.2
Potentially Recoverable Leakage -Communities without "Flow Profiles" (by multiplying Supply by 27.1 and 5.8%)	27.3	7.4	1.6
Total Potentially Recoverable Leakage All MDC Communities (rounded to nearest whole number)		73	16

The previous analysis attempts to place limits around existing estimates for potentially recoverable leakage within the communities supplied by the MDC. Implicit to this analysis is the assumption that existing data as reported to the MDC had varying degrees of reliability. In addition, some of the data probably have inherent bias; for example, estimates of unmetered consumption. It is hypothesized that previous estimates of potentially recoverable leakage have not accounted for the fact that estimated consumption (primarily for unmetered commercial, institutional and public facilities) would tend to be lower that the actual consumption. Estimates of a facility's water use tend to be based upon past estimates, sometimes going back several years, although the general trend of actual water use is likely to be increasing. Another reason that these estimates would tend to be low is the economic self-interest of the water customer (if it is a revenue account). The customer has a good idea of how much water he is consuming and if he thinks his estimated consumption (his water bill) is higher than it should be, he will immediately protest. On the other hand, if the estimates of his consumption is less than he thinks he is consuming, it is likely he will say nothing, and the low estimate continues until such time as it is discovered by the community water agency.

The effect of this underestimation is to increase the amount of unaccounted-for water and to overstate the amount of leakage. To what extent this factor influences estimates of potentially recoverable leakage can now only be surmised. However, further investigation to determine the influence of this factor is suggested.

Distribution and Number of Leaks

One of the objectives of this study is to develop a preliminary estimate of the costs to detect and repair potentially recoverable leakage. The cost to repair the leakage will depend on three main factors: the number of leaks, the size of these leaks and their location. Using data from Boston's leakage detection and repair program over the past four years, a rough approximation of a range of the number of leaks within all of the MDC member communities can be developed.

Since 1976, the Boston Water and Sewer Commission has conducted a comprehensive leakage detection and repair program. The firm of Pitometer Associates, has discovered some 318 previously undetected leaks. These leaks accounted for a flow rate of approximately 8,345,000 gallons per day and ranged in size from approximately 1.3 gpm up to 190 gpm. For purposes of this analysis, it will be assumed that a leak of 1.3 gpm is the lower size limit of leakage currently detectable with existing equipment under most conditions. Discussions with a Boston area leakage detection firm indicate that the lower size limit for leak detection is somewhere between 1 and 5 gpm. Under normal conditions with traffic and background noise, the lower

range of detection is probably closer to 5 gpm. A leak of 1.3 gpm corresponds to a hole of 1/12 of an inch in diameter in a distribution pipeline at 50 psi pressure. As a corollary it will also be assumed that a 1.3 gpm leak is the upper limit of the leakage component in what is termed the unavoidable leakage in a system, estimated herein to be 250 gallons per day per mile of pipe per inch of pipe diameter.

The results of Boston's detection and repair program over the past four years are summarized in Table 5. The detected leaks can also be tabulated according to size as shown in Table 6. Table 6 can be expressed graphically as a histogram. This is shown in Figure 1. Finally, cumulative detected leakage (as a function of leak size) is shown in Figure 2.

An attempt was made to project the size distribution of Boston's leakage to all of the MDC community distribution systems. However, it was felt that data was insufficient to draw even very broad conclusions about the member community systems as a whole.

Although a distribution curve for the size of leaks was not developed, some tentative assumptions were made on the number of leaks. In Boston the mean size of leaks detected produced a flow of about 26,250 gpd (18.2 gpm). However, this figure probably does not represent a true average of the size of undetected leaks in Boston's system. As in any leakage detection program, emphasis is first placed on areas where high amounts of leakage is suspected. These are likely to be areas with leaks larger than the average size. Therefore, to be more representative of what could be termed a more typical leak, Boston's average size leak will be multiplied by a factor of 0.6. (There is no quantitative basis to validate this adjustment. It was based upon judgement after discussions with Boston regarding the initial emphasis of their leakage detection program. The Town of Arlington, Mass., estimated a savings of approximately 2,306,000 gallons per day in the detection and repair of 110 leaks between 1974 and 1979. The resultant average was approximately 21,450 gallons per day or 15 gpm per leak). It will therefore be postulated that the average size of Boston's potentially recoverable leaks is 16,000 gpd. Upon projecting this figure it is estimated that there are between 1000 and 4560 leaks in the member community systems. In order not to imply a greater accuracy than is intended, these figures will be rounded off to between 1000 and 5000 leaks. Therefore, given the assumptions stated herein, it is estimated that between 16 and 73 million gallons of water per day are lost through between 1000 and 5000 potentially recoverable leaks in water-user community distribution systems. Since the community distribution systems contain about 5000 miles of pipeline, this number of undetected leaks appears possible. It should be noted that the leakage that we have been discussing is hidden, and would not otherwise be discovered. It is assumed that leaks appearing on the surface are repaired soon after they appear.

TABLE 5

Boston Water and Sewer Commission
Results of Leakage Detection and Repair Program

1976 - 1979

Type of Leak \ Year	1976	1977	1978	1979	Total
Blow Off	- / -	- / -	- / -	1 / 6,000	1 / 6,000
Valve	1 / 10,000	- / -	- / -	- / -	1 / 10,000
Meter	1 / 10,000	- / -	- / -	- / -	1 / 10,000
Service	14 / 335,000	52 / 1,440,000	13 / 550,000	81 / 3,541,000	160 / 5,866,000
Fire Main	1 / 250,000	- / -	- / -	5 / 240,000	6 / 490,000
Supply Main	5 / 320,000	4 / 190,000	2 / 550,000	9 / 590,000	20 / 1,650,000
Hydrant	17 / 46,000	24 / 88,000	11 / 28,000	77 / 151,000	129 / 313,000
Total	39 / 971,000	80 / 1,718,000	26 / 1,128,000	173 / 4,528,000	318 / 8,345,000

# of Leaks / Est. Water Saved (gpd)

Data taken directly from annual summaries compiled by Pitometer Assoc. for Boston Water and Sewer Commission.

TABLE 6

Boston Water and Sewer Commission
Leakage Detection Program

1976 - 1979

Size of Leak (gpm)	Number of Leaks	Percent of Total
1.3-10	115	36.2
10-20	144	45.3
20-30	13	4.1
30-40	9	2.8
40-50	14	4.4
50-60	0	0
60-70	20	6.3
70-80	0	0
80-90	0	0
90-100	0	0
100-110	0	0
110-120	0	0
120-130	0	0
130-140	0	0
140-150	0	0
150-160	0	0
160-170	0	0
170-180	1	0.3
180-190	0	0
190-200	2	0.6

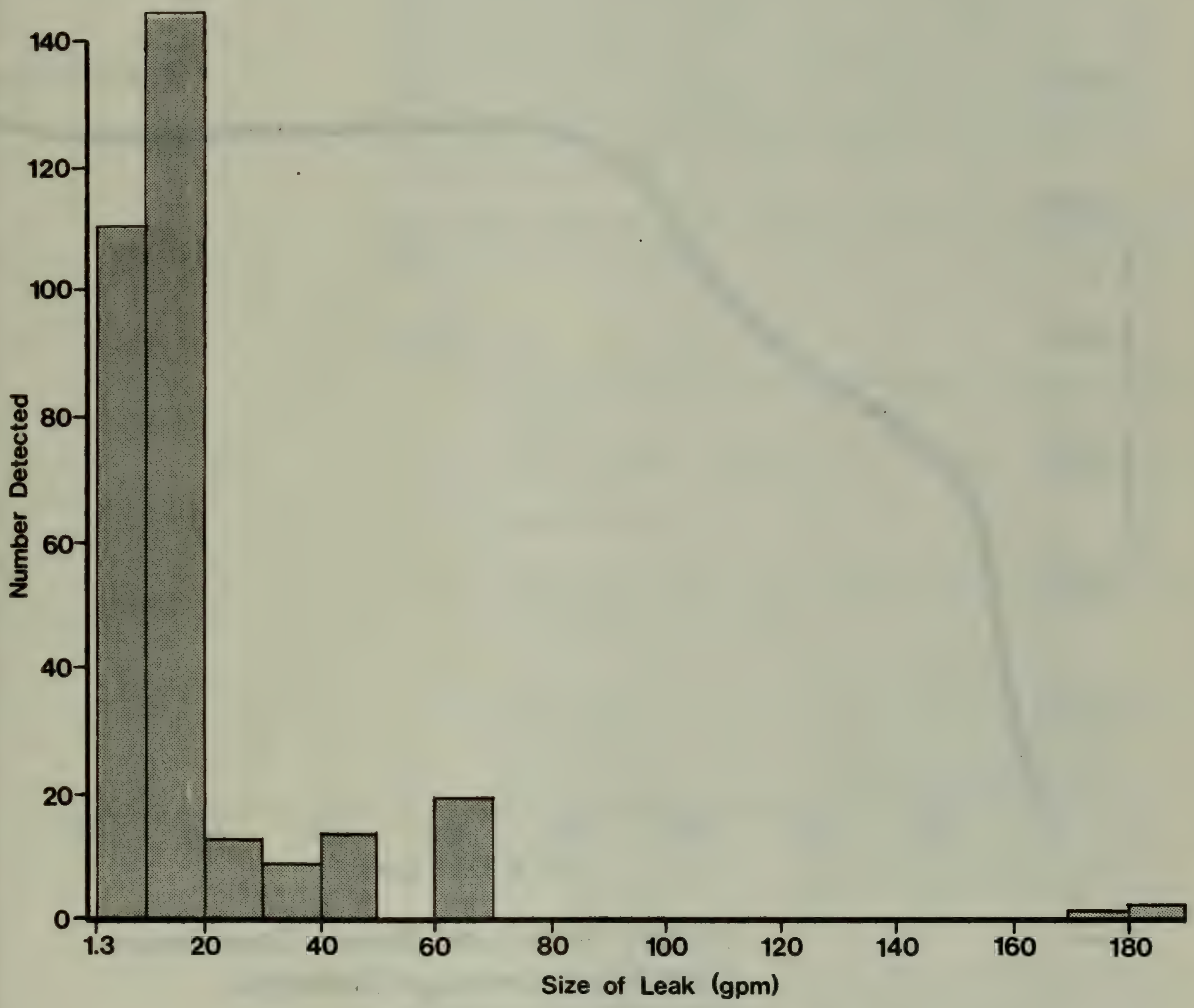


Figure 1

Boston Water and Sewer Commission
Leakage Detection Program
1976 - 1979

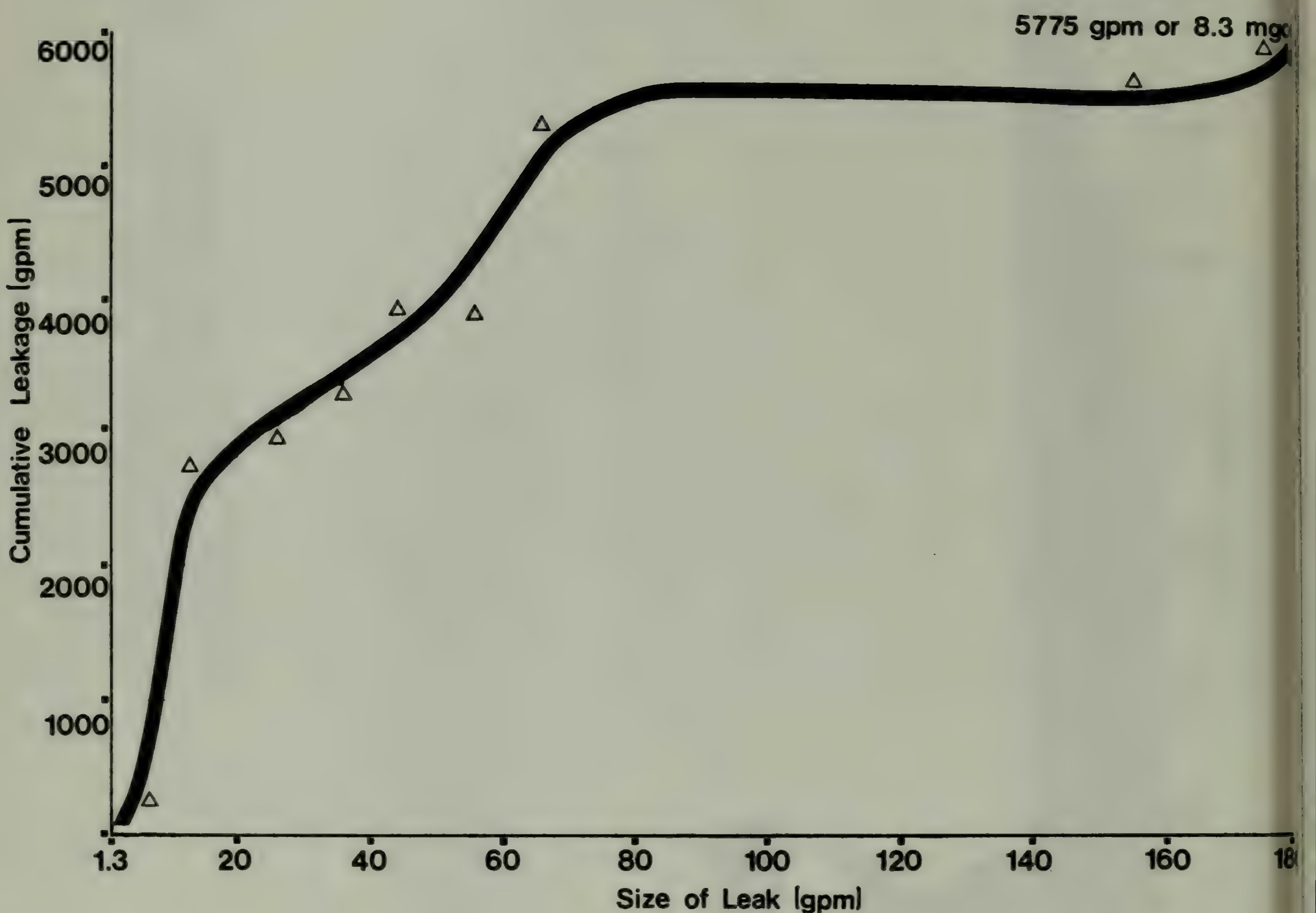


Figure 2

Boston Water and Sewer Commission
Cumulative Leakage Detected
1976 - 1979

Order-of-Magnitude Cost Estimates

An order of magnitude estimate of direct costs to locate and repair a "typical" leak is shown on Table 7. Other indirect costs are also associated with leak repair.

Examples of these costs are the disruptions resulting from streets being torn up, traffic control expenses, leakage program administration expenses, and the inconvenience of temporary water cut-offs when repairs are being made. These costs are not quantified in this analysis but need to be added to the total in order to have a realistic estimate of the costs of leakage detection and repair programs for MDC user communities. More refined analyses of the costs of leakage repair should investigate these issues.

Using the estimated direct cost from Table 7, an estimate is made of the size of leak which is economical to repair as follows:

Assumptions:

- Estimated cost to locate and repair a "typical" leak - $2000.
- Life of repair - 20 years;
- Discount rate - 8 percent;
- Cost of water and cost to locate/repair leak will increase (or decrease) by the same rate for the 20 year period of analysis;
- Cost of supply, transmission, treatment and distribution to the point of leakage is $ .50 per 1000 gallons. Presently, the MDC charges member communities $0.24 per thousand gallons of water. The amount that the communities charge customers varies between $0.24 and over $1.00 per thousand gallons. Fifty cents per thousand gallons appears to be a typical rate. The analysis is set up so that the reader can insert any cost for water and easily obtain the economical repair point.

If the present worth of the loss of water over the 20 years is greater than the cost to locate and repair a leak today, then it would be economical to locate and repair the leak.

Present Worth = Annual Value of Water Saved
Where
Present Worth = $2,000
i = 8%
n = 20 years
Annual Value of Water Saved=?

TABLE 7

ORDER-OF-MAGNITUDE COST ESTIMATE[1]

"Typical" Leak - Detection and Repair

ITEM	UNIT	QUANTITY	UNIT COST	TOTAL COST
Foreman	Hour	8	10.00	80.00
Equipment Operator	Hour	8	8.00	64.00
Truck Driver	Hour	8	7.50	60.00
Laborers	Hour	24	6.80	163.20
Backhoe	Hour	8	30.00	240.00
Dump Truck	Hour	8	20.00	160.00
Air Compressor & Pneumatic Hammer	Hour	8	7.50	60.00
Compactor	Hour	8	3.50	28.00
Pickup Truck	Hour	8	6.50	52.00
Repair Clamp	Each	1	75.00	75.00
Select Backfill	Cu. Yd.	4	20.00	80.00
Hot Mix Asphalt	Ton	8	25.00	200.00
			Subtotal	$1,262.20

Detection costs will vary. Based upon limited data from Boston, the cost to locate an average leak by means of a leak detection survey is approximately estimated to be :	600.00
Total detection and repair :	1,862.20
Round off to:	$2,000.00

[1] It is emphasized that this is an approximate estimate of direct costs. Costs for detection and repair of some leaks will be less; for others, the cost will be more. It is considered that $2,000 is a reasonable estimate for the typical or frequently-encountered leak in a public roadway in an urban or suburban area.

Solving the equation indicates that if the value of the water lost through a leak is more than $203.70 per year, then it is economical to repair that leak. At a cost of $0.50 per thousand gallons, this would be represent a leak greater than 0.8 gallons per minute. It was previously mentioned that existing leak detection equipment has a practical lower limit of detection of a leak of between 1 and 5 gpm. This implies that if a leak is detectable, it is economical to repair. However, this is not always true because additional costs are involved as explained in the preceeding sections. Also inherent in this analysis is the assumption that the leak would go undetected for 20 years. This assumption will need to be evaluated in future phases.

Assuming that there are between 1000 and 5000 economically recoverable leaks with an average repair cost of approximately $2,000 each, the direct costs of locating and repairing the potentially recoverable leakage in the MDC district community systems, would be between $2,000,000 and $10,000,000.

However, leakage detection programs must be carried out periodically. All the leaks in an entire municipal system cannot be repaired even in a year's time. Even if this were possible, new leaks are always occurring. In other words, some portion of the potentially recoverable leakage will be recovered in the first year of a detection and repair program and additional portions in subsequent years.

As mentioned throughout this analysis, the estimates contained herein are based upon several simplifying assumptions, which if erroneous will affect significantly their accuracy. While the results are consistent with previous investigations, they are order-of-magnitude. Additional investigation and study are recommended to improve the accuracy and narrow the limits of their reliability.

Comparison with Other Municipal Water Distribution Systems

Periodically, the American Water Works Association (AWWA) conducts surveys of distribution systems to characterize the extent of unaccounted-for water within these systems.

The results of the 1970 AWWA Survey, for 354 systems are summarized in Table 8.

TABLE 8:

1970 AWWA Survey

Size of System	No. of Systems	Mean Value (Percent) Unaccounted-for Water*
Less than 2000 mg/yr	212	14.99
2000-5000 mg/yr	72	12.23
5000-10,000 mg/yr	36	11.42
10,000-50,000 mg/yr	28	10.77
More than 50,000 mg/yr	6	9.02
	354	

* As used in the AWWA Survey, unaccounted for water is defined as the ratio of metered water sales to water delivered to the distribution system.

On the basis of the previous studies, it appears that virtually all MDC water-user communities would exceed the mean value of unaccounted-for water for their respective size.

In order to verify this fact, two additional pieces of information will be required: up-to-date statistics regarding metered sales in the communities, and further analysis of the AWWA survey to determine if any adjustments were made to "metered sales" to account for known but unmetered water uses. Furthermore, it is suspected that most MDC member community water distribution systems may be older than the average system reported in the AWWA Survey. Moreover, the severe winters in New England may cause more distribution system breakage and resultant leakage. These factors should be investigated in a more detailed analysis of recent AWWA surveys.

LEAKAGE WITHIN MDC DISTRIBUTION SYSTEM

Previous Studies

Most studies of unaccounted-for water have focused on community distribution systems as opposed to leakage within the MDC transmission and distribution system. The MDC Water Division Statistical Office does perform a weekly water balance to determine the amount of unaccounted-for water within a limited portion of the MDC distribution system. A sketch of the system is shown in Figure 3. The procedure used is as follows:

> Weekly readings for meters 50 and 63, which measure the volume of water supplied to the Boston Low Service Distribution from Weston Reservoir are reported to the Statistical Office. The total flow for the week is converted to an average daily flow. The Sudbury Section of the Water Division reports daily flows in Norumbega Supply Pipelines 3 and 4, and also the reading at meter 142 which

measures flow into the City Tunnel. These are converted to average daily flow values. The above values are then totaled, and a correction for a change in storage in Spot Pond Reservoir is made. (Spot Pond is a large distribution reservoir located in Stoneham. Its capacity is 1,838 million gallons. Consequently, fluctuations in its elevation can be significant with respect to short term water accounting--1 foot equals approximately 100 million gallons--however, over the long term, fluctuations tend to cancel each other). The flow is then adjusted for flow to non-District members. Once a value has been determined, it is compared to the sum of readings of revenue meters. The difference is expressed as a percentage of total flow.

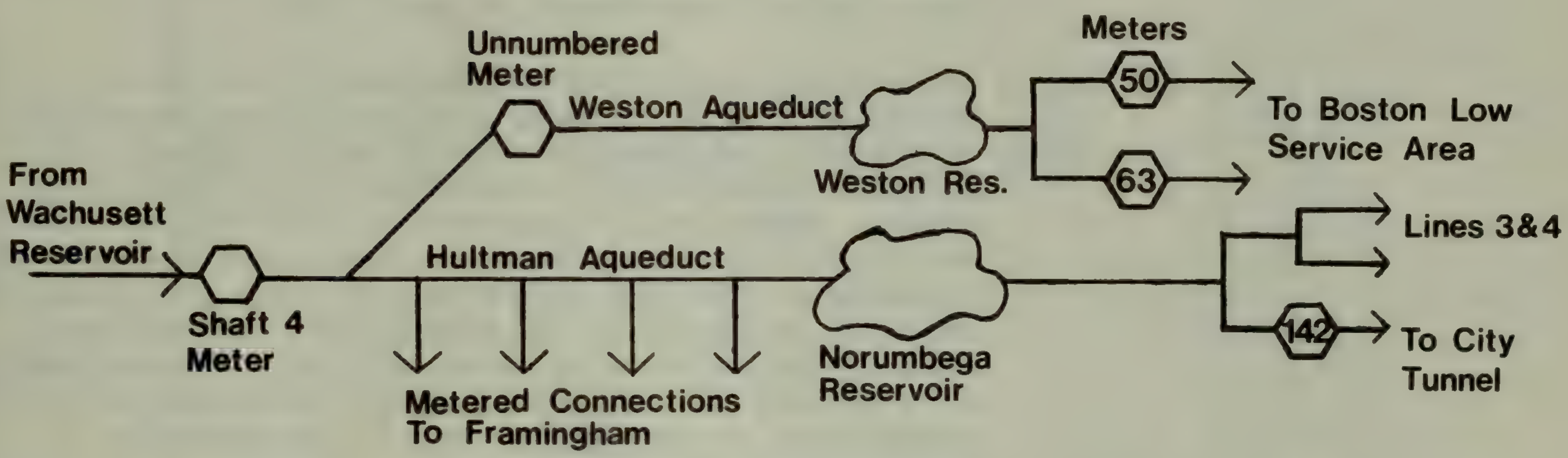


Figure 3 MDC Distribution System Schematic Diagram

The source of data for the previous computations are as follows:

Meter 50	Distribution Section Meter Readings
Meter 63	Distribution Section Meter Readings
Flow in lines 3 & 4	This value is reported to the Statistical Office by the Sudbury Section. It is determined by measuring flow in Hultman Aqueduct at Shaft 4, deducting flows to Weston Aqueduct and to Framingham, adjusting for a storage change in Norumbega Reservoir and deducting the volume of water into the City Tunnel as measured by Meter 142.

Meter 142 — Read and reported by Sudbury Section of Water Division.

All of the meters are venturi type, and because of access problems, some are extremely difficult to check or calibrate. Varying degrees of accuracy can be assigned to each input of the water balance, the computations carried out, and a range of expected values determined. Through interviews with MDC staff members, a qualitative estimate of the accuracy of each piece of input information was obtained.

With the exception of Meter 142, it was felt that all other meters which enter into this calculation were reasonably accurate. The MDC reported a low level of confidence in Meter 142.

In the following analysis, all meters judged to be reasonably accurate will be assigned a range of $\pm$ 5%. Meter 142 will be assumed to vary $\pm$ 10%.

The computational technique employed by the MDC is performed as shown on Table 9 using assumed ranges of accuracy in the data. The result should reflect the probable range of flow values measured by these master meters. Ranges will be assumed for District and non-District revenue meters and ranges of deviations will be derived. The week ending May 10, 1980, was chosen for analysis, because flow information for this week was readily available and it appeared to be a typical week. Although this was not confirmed by a close analysis of the weekly data, it was assumed that it was generally representative and would serve to illustrate the computations.

The most loss would occur when flow through master meters was at the high end of its range, and the flow through revenue meters was at the lower end of its range. The difference betweem the two, known as deviation, would then be maximized.

Discussion of Results

This analysis was only performed for one week's flow. The results are therefore only an indication of the sensitivity of these computations for a certain range of flow. However, the same analysis performed for other weeks could be expected to provide similar results.

Two preliminary conclusions are apparent. First, the MDC's weekly consumption analysis is not highly sensitive to moderate variations since instantaneous errors will be averaged over a week's time. The analysis provides a reasonable estimate of leakage from a portion of the distribution system. Secondly, although Meter 142 is reported to be questionable, its inaccuracy has no effect on the Weekly Consumption Analysis. The reason for this is that its reading is subtracted from the "Draft from

SENSITIVITY ANALYSIS OF MDC
WEEKLY CONSUMPTION ANALYSIS
Million Gallons per Day -

	Minimum Potential Loss	Metered Value	Maximum Potential Loss
Flow in Hultman Aqueduct			
(Shaft 4 Meter minus Weston Aqueduct Meter	231.38[1]	250.14	268.90[1]
Less Flows to Framingham	8.13	7.74	7.35
Less Storage Change (Norumbega)	1.14	1.08	1.03
Draft from Norumbega	222.11	241.32	260.52
Less Flow to City Tunnel (Meter 142)	169.71	154.28	135.85
Flows in Lines 3 and 4	52.40	87.04	124.67
Plus Meter 50	13.59	14.30	15.02
Plus Meter 63	32.48	34.19	35.90
Plus Meter 142	169.71	154.28	135.85
Spot Pond Correction (Minus)	-2.52	-2.40	-2.28
Total Flow-Master Meters	265.66	287.41	309.16
Flow Through District Meters	286.52	272.88	259.24
Flow Through Non-District Meters	2.88	2.74	2.60
Total - Revenue Meters	289.40	275.62	261.84
COMPARISON OF TOTALS			
Master Meters	265.66	287.41	309.16
Revenue Meters	289.40	275.62	261.84
Deviation	-23.74	11.79	47.32
Deviation as Percent of Total	0[2]	4.1%	15.3%

[1] This value is the result of a difference between two meter readings. To result in the "min. pot. loss", this difference would be minimized. This occurs when the Shaft 4 meter records low, and the Weston Aqueduct meter records high. If the assumed range of accuracy for these meters is ±5 percent, then the lower limit of the range of accuracy for the difference will be -7.5 percent in the range of flows measured by these meters. The same would apply to the "max. pot. loss", and the upper limit of the range of accuracy would be +7.5 percent.

[2] Negative deviation is meaningless.

Norumbega" by the Sudbury Section to arrive at the "Flow in Lines 3 and 4". Its reading is later added to "Lines 3 and 4" (along with Meters 50 and 63 and Spot Pond Correction) to arrive at "Total Flow-Master Meters". In summary, the reading from Meter 142 is added and then subtracted in the same computation, so its value is irrelevant for purposes of this computation.

The Weekly Consumption Analysis does have some limitations. Most significant is that it is limited in geographical scope. It accounts for water only from Norumbega Reservoir eastward in the City Tunnel and Lines 3 and 4, and from Chestnut Hill Reservoir eastward in lines 1 and 2 (Boston Low Service). There are portions of the MDC transmission and distribution system for which there is no knowledge of losses. (The MDC reported that data is available to calculate potential leakage from the Chicopee Valley Aqueduct. This analysis was not performed in this study but should be done in future phases). Consequently, no general conclusions concerning losses within the total MDC system can be made at this time. One means of broadening the geographical scope might be to take the meter reading at Shaft 4 and compare this to the sum of all District and appropriate non-District revenue meter readings.

RECOMMENDED STUDIES TO REFINE LEAKAGE ESTIMATES

Additional studies and data are needed to refine the estimates of potentially recoverable leakage and related detection and repair costs. They include the following:

MDC and Community System

- Evaluate the amount of potentially recoverable leakage that occurs between leakage detection surveys using different assumptions of survey frequency. This amount must be provided for in water supply planning.
- Evaluate the feasibility and potential of pressure reduction to reduce leakage in the high pressure portions of the MDC and user community systems.

Community Systems

- Obtain current census data;
- Obtain current Water Services and Metering Reports;
- Conduct interviews and evaluate data to improve the estimates of:
  - non-revenue unmetered water;

- minimum flows of industrial, commercial, and institutional and domestic users (for use in parallel analysis); and

- Compare current records of water usage against previous estimates of unmetered usage in representative communities which have recently installed meters on previously unmetered services.

- Interview leakage detection firms and communities that have conducted leakage detection and repair programs to refine estimates of:

  - leak size distribution;
  - detection survey costs;
  - direct costs of repair;
  - indirect costs of repair; and
  - size of detectable leaks.

- Evaluate quantities of water released at ends of pipeline mains through "constant blowoffs" to prevent stagnation and review other operational losses such as distribution reservoir evaporation and seepage;

- Using the data obtained from the above data searches and studies, develop a refined range of potentially recoverable leakage and associated detection and repair costs;

- Evaluate state-of-art, availability and feasibility of using mathematical models to predict potentially recoverable leakage in the MDC user communities; and

- Review the data used by the AWWA survey of unaccounted-for water in other community distribution systems and revaluate the comparisons of these findings with the estimates made for the MDC user communities.

MDC Transmission and Distribution Systems

- Obtain and compare flow data from meters at Shaft 4 and Shaft A to refine the level of confidence in accuracy of the Shaft 4 meter;

- Check the accuracy of key master meters including the Weston Aqueduct meter, and meters 142 and Shaft 4. Evaluate and recommend checks on other master meters which could be used to develop water balances on independent portions of the system;

- Evaluate the present MDC master metering system, as it relates to detecting leakage, and recommend additional devices or methods that could be used to improve estimates of leakage;

- For portions of the system without master meters, or where master meter readings may be inaccurate, check flow estimates by hydraulic simulation analyses;

- Obtain data on present estimates of reservoir leakage and evaporation and operational releases and losses; and,

- Using the data obtained from the above studies and analyses, develop a leakage estimate for the entire MDC transmission and distribution systems (including the Chicopee Valley Aqueduct).

A P P E N D I X

SUBJECT TO CORRECTION

METROPOLITAN DISTRICT COMMISSION - WATER DIVISION
COMPARISON OF AVERAGE DAILY QUANTITY OF WATER SUPPLIED

Community	February Period 1979		February Period 1980		Jan. to Feb. 1979 Running Average		Jan. to Feb. 1980 Running Average		Average For the year 1979	
	*M G D	**G C D	M G D	G C D	M G D	G C D	M G D	G C D	M G D	G C D
Arlington	4.716	94	4.614	92	4.507	90	4.689	93	4.772	95
Belmont	2.543	92	2.798	101	2.545	92	2.688	97	2.978	108
Boston	143.385	225	133.968	210	141.791	222	135.797	213	137.288	215
Brookline	7.267	137	6.529	123	7.159	135	6.857	129	7.558	142
Chelsea	3.131	125	3.213	128	3.115	124	3.145	125	3.169	126
Everett	8.252	208	7.982	201	8.139	205	7.907	199	8.500	214
Lexington	5.302	163	4.345	135	5.307	163	3.973	122	5.304	163
Lynnfield W.D.	.410	87	.445	95	.388	83	.415	88	.423	90
Malden	6.108	109	5.356	96	6.021	108	5.175	93	6.139	110
Marblehead	2.208	102	1.847	86	2.216	103	1.838	85	2.265	105
Medford	9.549	157	10.103	166	9.395	155	9.908	163	8.755	144
Melrose	2.476	77	2.321	72	2.598	81	2.266	70	3.095	96
Milton	3.663	135	3.143	116	3.630	133	3.002	110	3.124	115
Nahant	.391	93	.379	90	.370	87	.377	89	.434	103
Newton	9.416	106	9.826	110	9.429	106	9.596	108	10.468	117
Norwood	3.805	122	4.387	140	3.866	123	4.415	141	4.116	131
Quincy	13.488	147	11.086	121	12.858	141	11.883	130	11.766	129
Revere	5.101	124	4.934	119	4.943	120	4.587	111	5.105	124
Saugus	4.150	168	3.738	151	3.888	157	3.545	143	4.032	163
Somerville	9.113	113	9.805	122	8.950	111	9.593	119	9.487	118
Stoneham	4.336	201	4.045	188	4.075	189	3.773	175	3.901	181
Swampscott	2.085	145	1.798	125	2.096	146	1.864	130	2.090	146
Waltham	10.819	191	10.638	187	10.806	190	10.718	189	11.496	203
Watertown	4.903	136	4.303	119	4.943	137	4.299	119	4.549	126
Winthrop	2.024	99	1.986	98	2.132	105	1.977	97	2.095	103
Fully Supplied District	268.641	170	253.589	160	265.167	168	254.287	161	262.909	166
Cambridge	--		--		--		--		--	
Canton	.918		.979		.922		1.047		1.217	
Needham	.243		--		.439		.042		1.096	
Peabody	.001		2.013		.612		2.586		.496	
Wakefield	1.503		1.205		1.381		1.263		1.612	
Weston	.838		.800		.806		.745		1.044	
Winchester	.402		1.931		.385		1.954		.898	
Woburn			.933				.946		.527	
Partially Supplied District	3.905		7.861		4.545		8.593		6.890	
Total District	272.546		261.450		269.712		262.870		269.799	

March 14, 1980

TG/cmb

Millions of Gallons per day
Gallons Per Capita per day

1978

WATER SERVICES AND METERING REPORT

Community: **WALTHAM**

Water services (not including Fire Protection) on December 31, 1978.

a) Number of year-round services	12,202
b) Number of seasonal services	25
c) Number of temporary services	0
2. Total	12,227

. Fire Protection Services connected on December 31, 1978

a) Number of fire hydrants	1,539
b) Number of other fire services (i.e. sprinklers)	234
3. Total	1,773

. Metered and unmetered Water Services in 1978

a) Number of meters in working order	12,192
b) Number of meters <u>not</u> in working order	0
c) Number of unmetered services (<u>not</u> including fire services)	35
4. Total	12,227

. Water Sold including Metered and Nonmetered (estimated) in 1978

a) Volume sold to residential consumers (Gallons/year)	1,629,622,500
b) Volume sold to commercial consumers (Gallons/year)	1,418,325,900
c) Volume sold to industrial consumers (Gallons/year)	
d) Volume sold to public consumers (Gallons/year) (i.e. public building, schools, parks)	67,500,000
e) Volume sold to institutional consumers(Gallons/year) (i.e. churches, hospitals, schools, etc.	241,878,600
5. Total	3,357,327,000

1978

WATER SERVICES AND METERING REPORT (CON'T)

6. Metered water as recorded on consumer meters in 1978 — See Item #5

    a) Volume of metered water sold to **residential** consumers (gallons/year) ______

    b) Volume of metered water sold to **commercial** consumers (gallons/year) ______

    c) Volume of metered water sold to **industrial** consumers (gallons/year) ______

    d) Volume of metered water sold to **public** consumers (gallons/year) ______

    e) Volume of metered water sold to **institutional** consumers (gallons/year) 3,357,[illegible]

    6. Total — See Item #5

7. Unmetered (estimated) water delivered to consumers in 1978

    a) Volume of unmetered water sold to **residential** consumers (gallons/year) N

    b) Volume of unmetered water sold to **commercial** consumers (gallons/year) N

    c) Volume of unmetered water sold to **industrial** consumers (gallons/year) N

    d) Volume of unmetered water sold to **public** consumers (gallons/year) N

    e) Volume of unmetered water sold to **institutional** consumers (gallons/year) N

    7. Total ______

8. Non-Revenue unmetered water useage in 1978

    a) Volume used for Fire Protection (gallons/year) 3,000,0

    b) Volume used for main and sewer flushing, street cleaning (gallons/year) 2,000,0

    c) Volume used for public buildings or facilities (gallons/year) Meter

    d) Other unmetered uses (gallons/year) ______

    8. Total 5,000,0

WATER SERVICES AND METERING REPORT (CON'T)

Distribution System losses in 1978

a)	Total miles of water main in use on December 31, 1978 (miles)	154.4
b)	Volume of unavoidable leakage (gallons/year) i.e. (3000 gallons/mile)/day x 365 days x 9a.	169,068,000
c)	Volume of water lost due to leakage in excess of that in 9b. (gallons/year)	694,290,000
d)	Volume of water lost due to breaks in water mains. (gallons/year)	1,000,000
	9. Total (b,c,d)	864,358,000

Length of each size of main pipe

Length in feet of each size of main pipe, 4 inches and above, in use December 31, 1978

4" - 51,476 L.F.	39.00	
6" - 381,500 L.F.	433.52	
8" - 152,638 L.F.	231.27	
10" - 69,681 L.F.	131.97	
12" - 87,456 L.F.	198.76	
14" - 3,043 L.F.	9.07	
16" - 21,638 L.F.	65.57	
20" - 13,261 L.F.	50.23	
24" - 22,128 L.F.	103.58	
30" - 1,520 L.F.	8.64	= 1,267.61 inch miles

[illegible] 1117 = 153.4 [illegible]

11. Leakage Monitoring and control Program

a) Please describe your community's leakage monitoring and control program for 1978

A leakage survey has been requested, but the appropriation for the project has not been made.

b) Do you plan to have a leakage control program in the near future

If yes, please describe it.

If you do not have a program, and are not contemplating one please answer why.

If appropriation is made the leakage survey will be implemented.

12. Meter Maintenance Program

Please describe your existing meter maintenance program. Include number of new meters installed this year, number of existing meters recalibrated, repaired, or replaced, and your program for next year. If you do not have a program, please write "no program."

The City has undertaken a program of the replacement of all existing 5/8" to 2" meters with new remote read-out meters. The program is almost complete and 11,960 meters are now in use, with 160 being replaced this year.

WATER SERVICES AND METERING REPORT (CON'T)

. Do you have municipal water supplies which were shut down when you joined the M.D.C.?

a. Safe yield of the supply or supplies m.g.d.? None

b. Can the system be reactivated? No

c. Can you develop additional supplies? No

Describe.

d. Do you have engineering reports on these supplies? No

Please list each report.

. If you are a partial member

a. What is safe yield of your own supply? N/A

b. Do you have engineering reports on your supply? ______

Please list each report.

. Have you had a network analysis made of your Distribution System? Yes

a. If so, what year was it done? 1975

b. Where there any major deficiencies?

Please list. An extensive construction program of new transmission an distribution mains, with twin 4,000,000 gallon storage tanks, and pumping facilities is nearing completion.

16. EXPLANATIONS AND ADDITIONAL COMMENTS

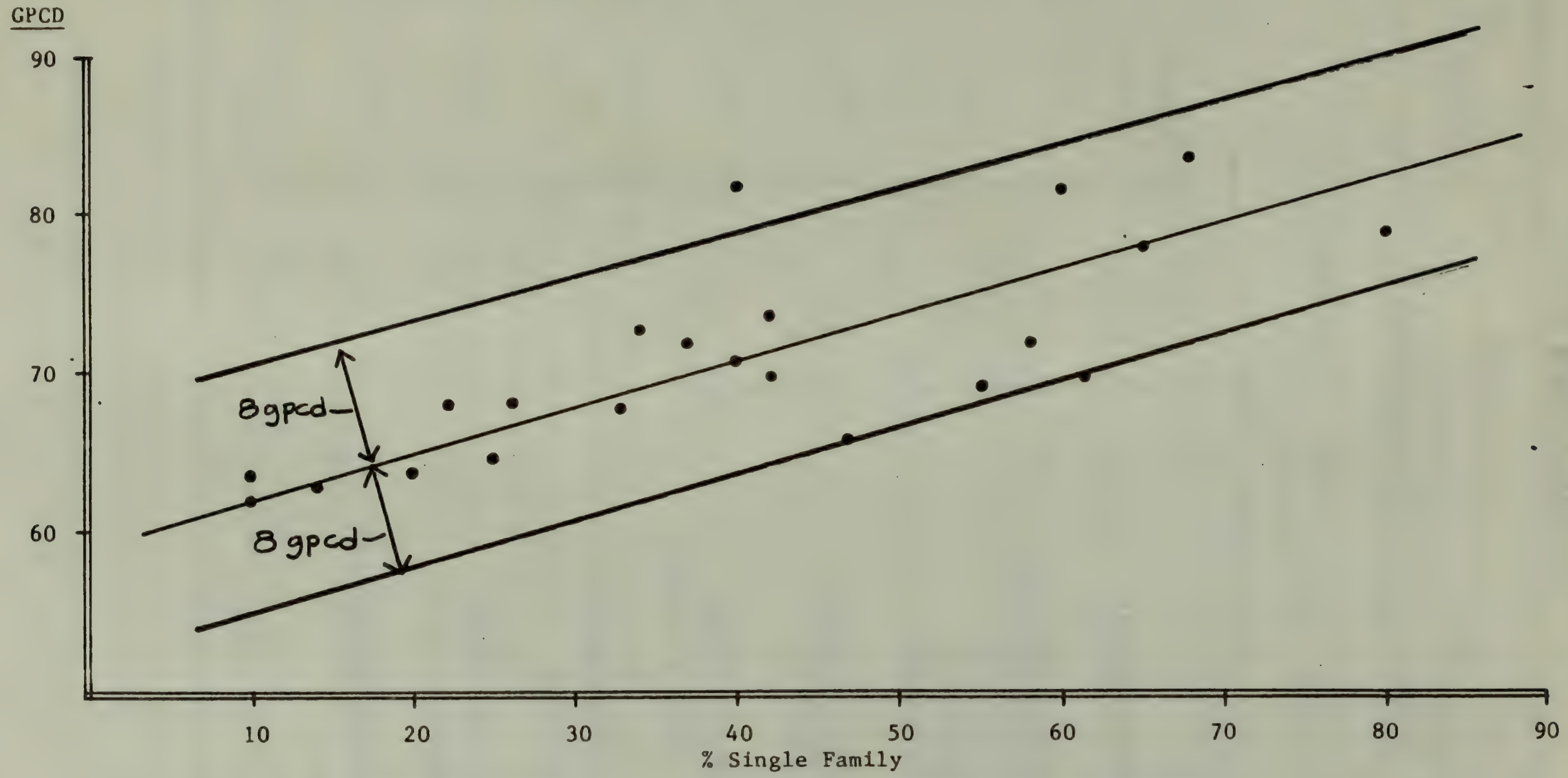
Edward F. Delaney

Signature and title of respondent Edward F. Delaney, P. E.

Director of Public Works

Date March 22, 1979

SCATTERGRAM: RELATIONSHIP OF DOMESTIC CONSUMPTION (gpcd)
TO RATIO OF SINGLE FAMILY HOMES



From Water Conservation - Recommendations for the Metropolitan District Commission; Linsky, H. S.; January 1980

BECHTEL

CALCULATION SHEET

CALC. NO. ______ REV. NO. ______

ORIGINATOR J.H. Eick DATE 6-13-80 CHECKED ______ DATE ______

PROJECT Northfield EIR JOB NO. 13323-100

SUBJECT Possible Range of Poten. Recov. Leakage SHEET NO. ______

City or Town Waltham

Population 56,700

	MDC Study	Maximum PRL	Minimum
1978 Total (GPCD)	204	204	204
Less Domestic	78	70	86
Less Domestic Meter Slippage	4	4	4
Less Comm'l., Indus. & Institutional	83	79	95
Less Comm'l, Indus. & Inst. Meter Slippage	4	4	4
Less Non-Revenue Unmetered	5	4	8
Less Unavoidable Leakage	6	5	7
Potentially Recoverable Leakage	24	38	0
Percent of Total	11.8%	18.6%	0

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TECHNICAL MEMORANDUM

CONCEPTUAL ENGINEERING STUDIES AND ORDER-OF-MAGNITUDE COST ESTIMATES OF ALTERNATIVE WATER SUPPLY SOURCES FOR AUGMENTING MDC SUPPLIES

Northfield Environmental Impact Study-Phase I: Basic Services

Prepared by Bechtel Incorporated

June 27, 1980

13323-100

SUMMARY

On the basis of information contained in previous studies, conceptual engineering designs and order-of-magnitude cost estimates were developed for a number of water supply alternatives to augment Metropolitan District Commission (MDC) water resources.

As there was no prior comparison of these alternatives for providing equivalent yields, the water supply potential of each alternative was developed to its estimated potential safe yield, or to 70 million gallons per day (mgd), whichever was less.

The facilities, potential water supply yields, and preliminary estimates of energy requirements and annualized costs as developed for each alternative in this preliminary phase of the EIR are summarized in Table 1. The alternatives are not listed in any particular order and were not ranked. Selection of recommended alternatives will be performed during future phases when the impacts and costs of development have been more accurately assessed.

In future phases of the Environmental Impact Report (EIR), additional studies should be performed in order to improve the level of confidence in the projected yields of each source and to define the intended operation, required facilities, costs, and environmental impacts of each. These studies include the following:

- Potential yield of each source during drought years;
- Operating regimes of the existing Northfield Mountain Pump Storage Project;
- Modifications required to the MDC system to accept new supplies;
- Impacts of ground water withdrawals on local rivers, lakes, wells, and habitats;
- Impact of future energy cost increases on annual operating costs;
- Impact of flood skimming on present/future downstream hydroelectric potential;
- Water treatment requirements;
- Alternative intake and outlet types and arrangements, water treatment processes, and conveyance facilities and alignments; and
- Combinations of alternatives.

The alternatives are individually described in the chapters which follow.

TABLE I

NORTHFIELD MOUNTAIN EIR - PHASE 1
PRELIMINARY SUMMARY OF YIELD, FACILITIES, ENERGY REQUIREMENTS AND COSTS OF ALTERNATIVES

Alternative	Developed Yield - Average Annual MGD	Facilities Required		Energy Requirements	Cost $/MG/Yr.	
Northfield Mountain						
o flood skimming-gravity option	70	Tunnel & Shafts	8'Ø - 10.2 mi.	81×10^6 kwh	230	280+Energy Costs****
		Water Treatment Plant*	Ozone - 375 MGD*	5×10^6 kwh*	50*	
o flood skimming-power option	70	Powerhouse	18 MW	54×10^6 kwh	270	320+Energy Costs****
		Tunnel & Shafts	10'Ø - 10.2 mi.			
		Water Treatment Plant*	Ozone - 375 MGD*	5×10^6 kwh*	50*	
Connecticut River Tributaries						
o Millers River flood skimming	70	Weir	Gated ogee - 200'		190	240
		Tunnel & Shafts	10'Ø - 7.8 mi.			
		Water Treatment Plant*	Ozone - 500 MGD*	5×10^6 kwh*	50*	
Merrimack						
o flood skimming	70	Water Treatment Plant	125 MGD	63×10^6 kwh		630
		Pump Plant	12,600 Hp	12×10^6 SCF(gas)		
		Pipeline	72"Ø - 29 mi.			
Upper Sudbury						
o reservoir watershed	21.9	Water Treatment Plant	30 MGD	2.3×10^6 kwh**		210
o river basin watershed	45	Pump Plant	250 MGD	9×10^6 kwh**		540
		Pipeline	2-66"-4 mi.			
		Water Treatment Plant	125 MGD			
Local Sources						
o abandoned or reserve supplies	31	Water Treatment Plants	31 MGD	19×10^6 kwh**		550
		Pump Plants	1200 Hp(Est.)**	3×10^6 SCF(gas)**		
		Pipelines	Various			
o Plymouth groundwater	70	Wells & Pumps	55-1.4 MGD/60 Hp	63×10^6 kwh		570
		Well collection pipelines	Various - 16 mi.			
		Reservoir	5 MG			
		Water Treatment Plant	70 MGD			
		Pump Plant	5,000 Hp			
		Pipeline	60"Ø - 33 mi.			
Desalting	70	Multistage Flash Plant	80 MGD	1.6×10^6 barrels oil***		4460
		Pump Plant	7400 Hp	48×10^6 kwh		
		Pipeline	60"Ø - 29 mi.			

Abbreviations

* If required, need for treatment is uncertain.

** Not stated in consultants report - rough estimate.

*** Roughly equivalent to 2860×10^6 kwh/yr.

**** Cost of off peak power not available.

MGD - Million gallons per day

mi. - miles

Ø - finished diameter

MW - Megawatts

MG - Million gallons

kwh - kilowatt hours - electricity

SCF - Standard Cubic Feet - natural gas

$/MG/Yr. - Dollars per million gallons/year

Hp - Horsepower

(1) The cost estimates included here are intended only to provide relative order-of-magnitude costs for the capital investment and operating costs of each alternative for the developed yield. Refinement of these estimates must be performed in future studies before [illegible]

INTRODUCTION

Conceptual engineering designs and order-of-magnitude cost estimates were developed for the following sources and options to respond to mandates by MEPA for Phase I:

- Upper Sudbury - watershed above Sudbury reservoir;
- Upper Sudbury - watershed above Framingham Dam #1 (including Sudbury Reservoir watershed);
- Merrimack River - flood skimming;
- Connecticut River Tributaries - flood skimming from Millers River to Quabbin Reservoir;
- Northfield Mountain - flood skimming to Quabbin Reservoir plus power generation;
- Local sources - reactivation of abandoned or reserve supplies within communities now served by MDC;
- Local sources - pumping from Plymouth ground water aquifer; and
- Desalting (Desalinization) - seawater desalting.

All of these alternatives have been studied previously by various agencies or firms, over a ten year period, usually with different water development objectives. The water quality of some sources evaluated in these studies has changed substantially since the studies were performed.

Additional water supply alternatives which do not require construction of physical facilities, were studied during Phase I. These alternatives: No Action, Conservation, and Quabbin Watershed Management are discussed in separate technical memoranda.

The principal objectives of the preliminary engineering task in Phase I were:

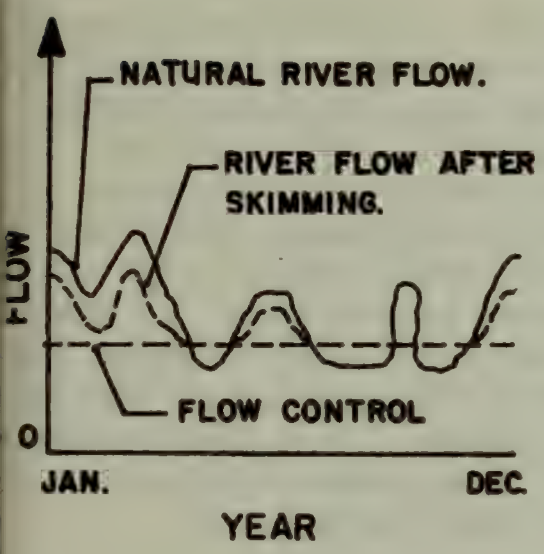
- To develop or review conceptual schemes for augmenting MDC supplies from the identified sources and options;
- To develop or update order-of-magnitude cost estimates for the conceptual schemes; and
- To identify information or studies needed for future phases of the EIR.

The conceptual schemes presented here were developed on the basis of the information contained in previous studies and reports. Some alternatives, such as the Upper Sudbury and Local Sources-Abandoned or Reserve Supplies, were adopted as presented in earlier studies. During development of Phase I conceptual designs and order-of-magnitude cost estimates, numerous assumptions had to be made concerning stream flows, existing facilities, water quality, facility costs and other data. No attempt was made in this phase to evaluate impacts on other existing or potential users. For example, the impact of flood skimming on downstream hydroelectric production was not assessed. Analysis of other potential environmental impacts and costs of mitigating measures was also deferred. Verification or development of the requisite data and potential

Since facilities and costs required for developing small to moderate versus large supplies from a source could differ substantially, it became necessary to focus on a potential water supply requirement. For this phase, 70 mgd was selected as the average annual demand required to augment present MDC supplies. This value represents the additional 1990 demand projection stated in the 1978 "Massachusetts Water Supply Policy Statement". When new demand projections are available in later phases of the EIR, the facilities will be resized and reestimated to reflect the new demand projections. Because three alternative sources did not appear to have a safe yield potential of 70 mgd, the sizing criterion was modified to develop each alternative up to its estimated potential safe yield or 70 mgd, whichever was less.

Information on the maximum potential yield was not found in the studies reviewed for several of the alternatives. In addition, little information was provided on the assumptions and methodology used to develop estimated yield and the impacts of drought events. Accordingly, estimates of the maximum potential yield of each source are not reported in this study. If found necessary, these estimates could be developed in subsequent phases after refinement of the required yield. In lieu of estimates of maximum potential yield, the existing studies were reviewed to determine if the alternative could reasonably be expected to provide the 70 mgd yield objective selected above. The reviews performed are reported under the paragraph titled Yield for each alternative.

Phase I estimates of capital and operating costs were developed or evaluated from unit costs, cost curves, or other methods suitable for developing order-of-magnitude costs. The cost estimates included here are intended only to provide relative order-of-magnitude costs for the capital



investment and operating costs of each alternative for the developed yield. Refinement of these estimates must be performed in future studies before conclusions can be drawn as to the most economical alternative(s). Environmental, socioeconomic and mitigating measure costs are not included in this phase.

The term "flood skimming" is referred to in some of the descriptions of the alternatives. Flood skimming is the withdrawal of a portion of the natural river flow during flood periods. The impact on the river flow is illustrated in the left margin.

NORTHFIELD FLOOD SKIMMING

Background

During their NEWS studies, the COE evaluated development of the Connecticut River Basin to determine its potential for meeting Eastern Massachusetts water supply needs (USCOE, 1969). Four projects were identified. Two projects (Northfield Mountain and Hadley) would partially divert flood flows from the Connecticut mainstream. Two other projects (Tully and W. Deerfield) would partially divert flood flows from Connecticut River tributaries. Of the four, the Northfield Mountain and Tully were selected for detailed studies as a result of a 1970 meeting of various public agencies and interested groups. These two projects had the lowest annual costs for development of the four Connecticut River Basin alternatives considered.

In May 1970, the COE performed more detailed studies on the Northfield Mountain alternative. In their detailed studies, the COE concluded that this alternative project would be needed to provide about one half of the estimated 1990 water deficit in Eastern Massachusetts. At the time of the COE studies, the project had already been conceived by the MDC and Northeast Utilities, authorized by the Massachusetts State Legislature and certain reservoir related facilities partially constructed. (COE, 1969 & 1974b.)

For Phase I of the EIR, the method of flood skimming proposed by earlier studies was selected for development of conceptual layouts and order-of-magnitude cost estimates.

Depending upon the water surface elevation in the Northfield Mountain Reservoir, there is a gross water surface difference between Quabbin and Northfield Mountain Reservoirs of between 400 and 480 feet. This difference is more than would be required for water to flow by gravity from Northfield Mountain to Quabbin and a device for dissipating a portion of the extra differential (potential energy) would be required. This device could be either an energy dissipator or a powerhouse. Evaluation of a powerhouse was included in this study as an option to an energy dissipator.

Yield

Under legislation enacted by the Massachusetts State Legislature, flood skimming operations on the Connecticut River would only be permissible when river flows exceeded 17,000 cfs at the USGS gauging station at Montague.

In their Northfield Mountain Water Supply Project study, the COE estimated that the Connecticut River would exceed this flow rate for about 23% of the year, or 84 days. (USCOE, 1974b)

Assuming that the maximum authorized daily diversion of 375 million gallons was made on each of those days, the project would have a potential yield of 86 mgd. COE reports reference 84 and 85 mgd per year on a long term average annual basis but concluded that for "operational considerations" that the estimated yield available to Quabbin would be about 72 million gallons per day. It was therefore concluded that the 70 mgd flow augmentation objective of the Phase I study could be met by flood skimming when the Connecticut River exceeds a flow rate of 17,000 cfs measured at Montague.

Water Quality

Water quality data for the Connecticut River at Northfield are summarized in Table 2. Sources of this data are as follows: Water Quality Studies, Connecticut and Miller's River Quabbin and Wachusett Reservoir, New England Research Inc., 1972; Annual Report, Water Quality Monitoring of Connecticut River, Northfield Reservoir, Quabbin and Wachusett Reservoir for 1977-78, New England Research, Inc. December 1978, Massachusetts Department of Environmental Quality Engineering Division of Water Pollution Control; 1978.

Comparison of Connecticut River water quality with EPA Drinking Water Standards indicates the following parameters may not meet EPA Standards: turbidity, coliform bacteria, color, iron, manganese and pH. It has also been reported that ammonia nitrogen exceeds recommended limits of the USPHS. Some of these parameters are only marginally below Drinking Water Standards, and in general Connecticut River water at Northfield would be characterized as a good source for a domestic raw water supply.

EPA Drinking Water Standards are applicable at the point of entry into the domestic water supply distribution system. Connecticut River water would undergo some natural treatment while in Northfield Mountain Reservoir, and to a greater extent in Quabbin Reservoir. These processes include clarification, oxygenation, biological degradation, precipitation, bleaching and dilution. The evidence that this process is in effect is demonstrated by the fact that the quality of the existing feeder streams is considerably lower than the water quality at the Shaft 12 intake to the Quabbin-Wachusett tunnel.

Therefore, it is conceivable that Connecticut River water, after undergoing no treatment other than the natural processes of Quabbin Reservoir would meet drinking water standards when it entered the MDC distribution system. Although this may occur initially because of the high dilution of the diverted water, the treatment capacity of Quabbin Reservoir may diminish in the future as the accumulated diversions become a larger portion of Quabbin's

TABLE 2

CONNECTICUT RIVER AND NORTHFIELD RESERVOIR WATER QUALITY

Parameter \ Sample Location & Date	Turners Falls 1971 Monthly Composite (1)			Upstream of Turners Falls 1977-78 Monthly Comp. (2)			Grab Samples Near Northfield (3)		USGS Water Quality Data Merri. & Connecticut River 1979 (4)			Northfield Reservoir 1977-78 Monthly Composites (2)			EPA Drinking Water Regulations
	Min.	Mean.	Max.	Min.	Mean.	Max.	7/11/78	8/29/78	Min.	Mean.	Max.	Min.	Mean.	Max.	
Arsenic				<.005	<.005	<.005			0	.0006	.001	<0.005	<0.005	<0.005	0.05
Barium				<0.1		<1						<0.1	–	<1.0	1.0
Cadmium				<.005	<.005	<.005			0	.0013	.002	<0.005	<0.005	<0.005	0.010
Chromium				<.005	<.005	<.005			<0.01	.013	.020	<0.005	<0.005	<0.005	0.05
Lead				<.005	<.005	<.005			.006	0.010	.017	<0.005	<0.005	<0.005	0.05
Mercury	0	0.002	0.003	0.0004	–	0.002			<0.0005	0.0005	–	<0.0002		<0.002	0.002
Nitrate (AsN)				0.07	0.10	0.14	0.3	0.5	0.12	0.19	0.25	0.06	0.08	0.10	10.0
Selenium				<.001		<.005			0	0	0	<0.001	–	<0.005	0.01
Silver				<.005		<.005						<0.005		<0.005	0.05
Fluoride															
Chlor. Hydro				0	0	0			0	0	0				0.0002-0.1
Chlorophenoxys				0	0	0			0	0	0				0.01-0.1
Turbidity	2	+5.5	6	0.37	2	4.3	1.0	1.2	1	2.8	7	0.6	1.6	3.9	1 T.U.
Coliform (Total)	1000	+3000	5000	385		3050	1000	200	1300	10012	29000	193	+1235	>2.400	1 per 100 ml
Coliform (Fecal)	100	300	1000	6	305	2170	60	80	60	297	1000	0	148	860	
DO	8.5	+10	13.4	7.2	11.2	14.3	7.6		8.5	10.6	13.4	6.8	9.9	13.0	
Chloride	3	+10	12	6.2	9.1	12.5	5	11	4.6	6.9	8.0	7.5	10.2	14.7	250
Color	20	+22	28	15	20	30	30	15				15.0	21.4	25.0	15 cu
Copper									.002	.003	.004				1
T. Suspended Solids							2.0	8.0							
BOD_5							1.2	1.2							
Iron	0	0.2	0.5	0.12	0.41	0.8			0.100	0.33	0.72	0.8	–	2.06	0.3
Manganese	0	0.02	0.08	<0.02	0.12	0.39			0.03	0.04	0.05	<0.02	–	0.49	0.05
pH	5.6	+7.0	7.7	5.9	6.8	7.4	7.4	7.3	6.6	6.9	7.2	6.5	6.9	7.3	6.5-8.5
Sulfate				6.4	10.9	17.0			7.7	8.1	8.8	6.0	11.0	16.2	250
TDS															
Zinc	0	0.04	0.1	<.02	–	0.02			0.10	0.10	0.10	0.02	0.04	0.09	5
Sodium	3	+6	19	4.2	4.9	6.8						3.9	4.8	6.9	
Hardness ($CaCO_3$)	24	+40	65	21.2	33.4	44.5						20.0	35.3	54.5	
P (Total)							0.07	0.08				0.02	0.03	0.06	
Aluminum															
Calcium															
Total Alkalinity	20	+25	27	7.6	19.6	32.3	27	37	21	29	35	9.3	20.9	32.2	

Units are mg/l unless otherwise stated.

(1) New England Research, 1972
(2) New England Research, 1978
(3) Mass. DEQE, 1978
(4) USGS, n.d.

TABLE 2

total storage. Possible long term concerns for the assimilative capacity of the Quabbin Reservoir include over-enrichment and dissolved oxygen reduction, algae growths, increased coloration, somewhat higher levels of coliform organisms and increased turbidity.

In view of the water quality deficiencies of the Connecticut River water and the present uncertainty of Quabbin Reservoir's long term assimilative capacity, a means of treatment was evaluated for this Phase I study. This provides an indication of order-of-magnitude costs should treatment eventually be required.

Operation

Under the Northfield Mountain alternative a portion of the flood flows would be withdrawn from the Connecticut River for sixty eight days during the spring freshet period when river flows exceeded 17,000 cfs at the Montague gauge. During abnormally dry springs, flood skimming might also be extended to other periods of the year to develop the required yield. These flows would be withdrawn by the existing Northfield Mountain Pump Storage Project pump-generating plant located above Turners Falls Dam and pumped to the existing Northfield Mountain Reservoir. The water would be stored in space created in the Northfield Mountain Reservoir specifically for the diversion and uniformly released during the following 24 hour period to Quabbin Reservoir. From the Northfield Mountain Reservoir the water would flow in a tunnel by gravity to Quabbin Reservoir. If required, ozone would be injected into the water in the intake shaft and/or initial portion of the tunnel. After entering Quabbin Reservoir, the water would mix with reservoir water and gradually migrate to the Quabbin-Wachusett tunnel intake.

The NEWS studies assumed that the diverted flood flows would be extracted from Turners Falls Reservoir storage and replaced by river flows during the subsequent twenty-four hour period. Recent evaluations of present Northeast Utility operations indicate that this assumption might not be entirely valid for all river flow conditions and power operations. More information on present Northfield Mountain Pump Storage Project operation needs to be developed to determine the full range of potential conditions during flood skimming operations. The water quality of the river and Northfield Mountain Reservoir would be monitored on a daily basis during the flood skimming period and diversion would not start or would be stopped if already in progress when the water quality deficiencies exceeded predetermined standards. A similar facility may be necessary at the reservoir near the discharge point to monitor Quabbin Reservoir water quality.

Facilities

The facilities developed during the conceptual engineering study for the average annual 70 mgd objective are shown in Figure 1, briefly summarized below and later discussed in more detail.

-- Gravity and power options

- Existing Northfield Mountain Pump Storage Reservoirs and pumping facilities;
- Existing intake and venturi meter;
- Water quality monitoring stations and laboratory; and
- If necessary, ozone injection equipment.

-- Gravity option

- 8 ft. diameter concrete lined tunnel, 52,000 ft. in length;
- Energy dissipating structure; and
- Outlet structure and channel.

-- Power option

- 10 ft. diameter concrete lined tunnel, 52,000 ft. in length;
- 18 megawatt powerhouse; and
- Outlet structure and channel.

These facilities differ slightly from those developed in earlier studies. Other arrangements, sizes, and outlet locations are possible and should be evaluated in future phases. However, the above combinations of facilities should provide a reasonable basis for developing an order-of-magnitude estimate for the cost of delivering water via the Northfield Mountain gravity and power alternatives.

Existing Northfield Mountain Pump Storage Facilities

The subject facilities consist of lower (Turners Falls) and upper (Northfield Mountain) Reservoirs, an intake located about 5 miles upstream of Turners Falls Dam, underground pump-generators, and conveyance tunnels. During construction of Northfield Mountain Reservoir, 1,150 acre-feet of storage was added to the original upper reservoir storage capacity for the flood skimming operation described in this alternative. This additional storage capacity is

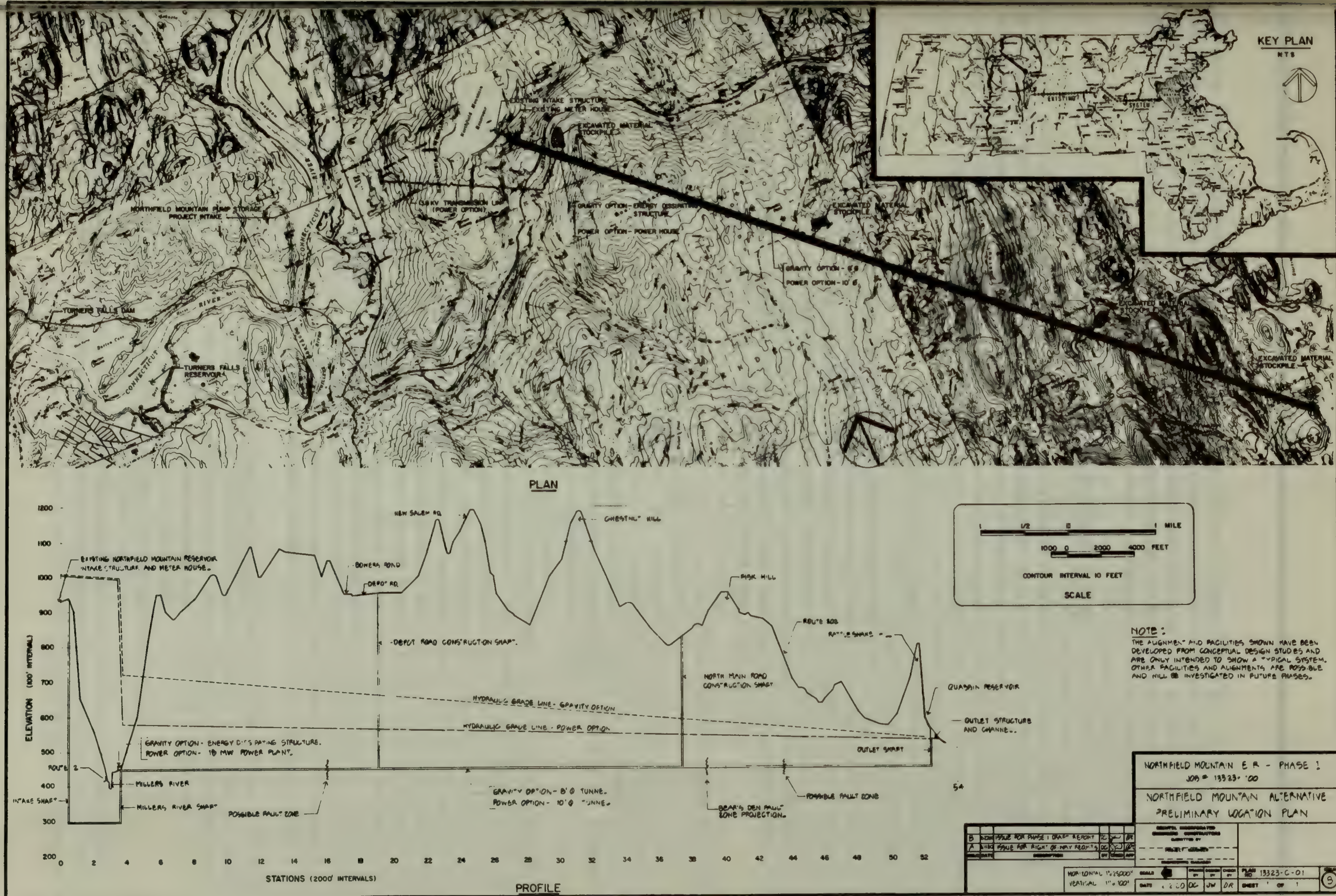


Figure 1

Originals at scale 1″ = 25,000′ are available for review at MDC or NCAC

equal to 375 million gallons, the maximum amount authorized for transfer to Quabbin in a 24-hour period. In addition, a gated intake structure, meter house, and 8 foot venturi flow meter were included during the original pump storage project construction.

Water Quality Monitoring Station

Water quality sampling stations were assumed on the Northfield Mountain Reservoir and near the outlet into Quabbin Reservoir. A certain standard of water quality would be required before any water would be released into Quabbin Reservoir. A laboratory would be required.

Water Treatment

As referenced in the paragraph on water quality, some type of treatment may be required to complement the long term natural treatment process of Quabbin Reservoir. For this study it appears that treatment with either chlorine or ozone would provide a satisfactory level of treatment. Current Connecticut River water quality may not meet EPA Drinking Water Standards for turbidity, coliform bacteria, color, iron, manganese, pH and possibly ammonia nitrogen.

Chlorine, however, has a number of detrimental side effects. In its inorganic aqueous forms, including chloramines, it is toxic to many species of desirable aquatic life at levels as low as 2 parts per billion. Moreover, chlorination of raw river water could result in formation of chlorinated organic compounds, some of which are suspected or potential carcinogens.

While all possible side effects of ozone have not been thoroughly investigated, it appears that it may be a safer choice than chlorine. However, additional studies are required to validate this tentative recommendation. Ozone treatment consists of two basic parameters - contact time and concentration. By increasing one the other can be reduced. It appears that if the ozone was injected into the intake shaft and/or beginning of the tunnel and properly diffused that the tunnel would serve as a contact chamber and permit lower concentrations of ozone. This possibility should be investigated in future phases.

Tunnel and Energy Dissipating Structure - Gravity Option

An 8 foot finished diameter reinforced concrete lined tunnel was selected to convey water from Northfield Mountain Reservoir to Quabbin Reservoir. The proposed tunnel alignment would be that selected by the COE/MDC. The alignment crosses the Millers River near Farley, the Bears Den Fault near Morse Village and terminates in Quabbin Reservoir at the base of Rattlesnake Hill.

Tunnel diameter would be smaller than those investigated in earlier studies. Since there is sufficient head to convey the design flow by gravity it was assumed that the larger diameter was selected for construction purposes. Information recently developed by Bechtel for another project suggests that an 8 foot tunnel would be possible to construct and may have a lower total cost. This assumption is important in evaluating the gravity versus power options and should be verified in future phases. The earlier studies indicate that the tunnel would probably be constructed in sound rock along most of its length and could probably be excavated by either a boring machine or conventional drill and blast method. (Ashenden, 1974 & COE 1974b) Supports would probably only be required in the upper portions of the shafts and when crossing the Bears Den Fault and other potential faults noted on Figure 1. For this phase, it was assumed that the lining would need reinforcement to withstand one half of the internal pressure and that the rock would provide sufficient resistance to withstand the remaining pressure. In view of the potential competency of the rock over most of the tunnel length, this may be a conservative assumption and should also be re-evaluated in the next phase.

The potential for using shotcrete should also be evaluated in future phases.

Potential areas for disposing tunnel excavation are indicated on the location drawing, Figure 1. These areas were selected from a study prepared for the MDC on potential spoil locations. (Farquhar, 1973)

Initially, a sudden enlargement energy dissipator was assumed to reduce the potential energy between Northfield Mountain and Quabbin Reservoirs. This device has been successfully used at other installations to reduce excess energy. However, in view of past difficulties with energy dissipators, a more conservative method was assumed for this phase. For order-of-magnitude cost purposes, it was assumed that the device would be two polyjet valves located just east of the Miller's River shaft at the entrance to the tunnel shown at elevation 450 in Figure 1. Provisions were also included to drain the tunnel for inspection and to house and maintain the valves and backup gates.

This method of dissipation is different than the large diameter scroll case type intake shaft studied by the MDC. Sudden expansion, scroll case, and other methods of dissipation should be evaluated in future studies.

Tunnel and Power Plant - Power Option

A 10 foot diameter reinforced concrete lined tunnel was selected to convey the water for this option. The larger tunnel would provide more available head for generation

of electrical energy. The tunnel alignment, invert elevation, concrete lining and all other tunnel characteristics are identical to that discussed under the gravity option.

An 18 megawatt (MW) power plant was located just east of the Miller's River shaft at the entrance to the tunnel shown at elevation 450 in Figure 1. For the 68 days of operation projected by this study, it was assumed that one 18 MW Francis unit would be less expensive than two smaller units and that all downtime for maintenance could be scheduled during the non-diversion period. A bypass pipe and pressure reducing valve were provided to maintain flow to Quabbin during emergency shutdown of the generator As in the gravity option, a drain line and operations building would also be provided.

Power generation was assumed only during diversion of Connecticut River flows to Quabbin for augmentation of MDC domestic water supply. Other power options are available which might provide higher net economic benefits. One additional option would be to use the powerhouse during the full year by releasing flows into the Millers River at Farley (and ultimately back into the Connecticut River at Turners Falls Reservoir) during the non-diversion period. This option would permit year round operation of the power plant and would also produce more energy capacity because of the higher head differential between the Northfield Mountain Reservoir and Millers River. The plant would in effect be an additional unit to the Northfield Mountain Pump Storage Project powerhouse. Under this option, power could also be produced only during peak demand periods which would increase the value of the energy generated. Power generation benefits assuming equivalent tunnel diameters for both the power and gravity schemes should also be evaluated in future phases.

Outlet Structure and Channel

The outlet structure selected for this phase of the study for both the power and gravity options would consist of a reinforced concrete tunnel shaft access chamber and stilling basin. Gates would be located on the outlet of the access chamber to permit dewatering of the tunnel without lowering the water levels in Quabbin Reservoir. The stilling basin would dissipate hiah exit velocities which would develop during low reservoir water levels. An 800 foot long, 25 foot wide riprap protected channel would be provided to convey water from the outlet structure to a natural low water channel in the reservoir. Location of the outlet structure will depend on several factors.

- Potential requirements for full treatment or removal of undesirable fish prior to release to Quabbin Reservoir;

- The need to provide a channel from the outlet to a natural low flow channel to avoid disturbing bottom sediments and organisms; and

- Potential requirements to encourage natural mixing of Connecticut River water with Quabbin Reservoir water.

These factors and alternative outlet arrangements need to be evaluated in more detail in subsequent phases.

Energy Requirements

This alternative is fairly energy intensive because of the power required to lift the water about 800 feet from the Connecticut River to the Northfield Mountain Reservoir. The pumping energy requirements are the same for both the gravity and power options, but partial recovery of the pumping energy would be achieved with the power option.

The estimated energy requirements are summarized below:

-- Gravity option

Pumping Plant -	81,000,000 kwh/yr
Water Treatment -	5,000,000 kwh/yr
Total	86,000,000 kwh/yr

-- Power option

Pump Plant -	81,000,000 kwh/yr
Water Treatment -	5,000,000 kwh/yr
Power Generated -	(27,000,000) kwh/yr
Total	59,000,000 kwh/yr

UNRESOLVED ISSUES/FUTURE STUDIES

Issues which need to be investigated in future phases of this study include the following:

- The present operating regimes of the Northfield Pump Storage Project;

- Potential modifications of the present pump-storage operations to implement this alternative.

- Requirements for eliminating or reducing the entrance of undesirable fish or aquatic species into Quabbin Reservoir;

- The expected periods of flood skimming and impac on river stages;
- Projections of future water quality in the Connecticut River at Northfield;
- Short and long term water treatment requirements and methods;
- Alternative facilities, alignments, power schemes, energy dissipating structures, water treatment methods, and outlet locations and arrangements;
- Impacts on hydroelectric power production;
- Impacts of drought years on the potential yields of this alternative;
- Collection of water quality data;
- Evaluation of the long term assimilative capacity of Quabbin Reservoir; and
- Feasibility of ozone treatment.

CONNECTICUT RIVER TRIBUTARIES

Background

As discussed earlier under the Northfield Mountain alternative, the COE evaluated the Connecticut River Tributaries alternative as a part of their NEWS studies. At the request of a consensus of agencies and private organizations in May 1970, the COE performed more detailed studies on the Tully Project which would partially divert flood flows from tributaries of the Connecticut River.

As a result, the Tully Project later referred to by the COE as the Millers River Basin, was selected as the Connecticut River tributary alternative for which conceptual studies and cost estimates would be developed for the EIR-Phase I study. For clarity, this alternative is called the Millers River alternative in this report.

The COE in their Millers River Basin Water Supply Project study developed three flood skimming schemes:

- Diversion from Millers River above Athol, yield 68.4 mgd;
- Diversion from Tully Flood Control Dam outlet works and Millers River above Athol, yield 75.8 mgd; and
- Diversion from four tributaries of the Millers River, yield 48.2 mgd.

The COE selected the second of the listed schemes (Tully-Millers River) on the basis of higher yield and potentially better water quality. (USCOE, 1973)

The first two schemes included construction of waste water treatment facilities at six upstream sources of pollution to clean up the river water quality prior to diversion.

However, since the NEWS study was performed, advanced water treatment facilities have been constructed upstream and the water quality of the river has improved significantly.

For the 70 mgd flow augmentation objective of the Phase I study, flood skimming of the Millers River above Athol was selected for development of conceptual layouts. As described in the next paragraph, diversion of the 70 mgd by flood skimming appeared feasible and the improved water quality in the Millers River suggested that the water quality advantage of the combined Tully-Miller scheme selected in 1970 has diminished.

Yield

In Appendix C of the Millers River Basin Water Supply Project, the COE (1973) summarized the results of several schemes which equated the potential diversion capacity of the facilities to yield. For example, for the Millers River they were able to develop a yield of 87.6 mgd by increasing the peak diversion flow rate to 2351 cubic feet per second (cfs). Interpolation of the COE flow rates versus yield indicated that the 70 mgd yield required for the Phase I study could be achieved by increasing the peak diversion rate from 730 cfs to 800 cfs.

Flood skimming would not be possible during the entire year. As a part of their study, the COE (1973) developed with the US Fish and Wildlife Service the minimum flows shown in Table 3 for the Millers River below the intake. In addition, the flow in the Connecticut River at Montague would also have to exceed 17,000 cfs before flood skimming would be permitted. This resulted in two controls on diversion:

1) Maintenance of minimum flows in the Millers River below the intake; and

2) Flow greater than 17,000 cfs in the Connecticut River at Montague.

Both conditions would have to be met before and during diversions from the Millers River. Under these controls, flood skimming would most likely occur during flood flow periods in February through June, and October through November.

No "safe yield" value for flood skimming from the Millers River was found in the COE (1973) report. However, brief inspection of the monthly flow-rate data contained in the report indicated that an average of 70 mgd could be diverted by flood skimming in most but not all years without violating the flow controls established for the Millers River. Information on the potential yield of the alternative during drought periods and the impact of the flood skimming on historical river hydrographs should be obtained from the COE or developed in future studies.

Water Quality

Water quality parameters for the Millers River are summarized in Table 4. Sources of data are "Water Quality Studies Connecticut and Millers River Systems and Quabbin and Wachusett Reservoirs, Massachusetts", New England Research, Inc. June 1972, and The Connecticut River, Water Quality Data 1978, Massachusetts Department of Environmental Quality Engineering, 1978. Also tabulated are (EPA)

Table 3

Millers River Flow Controls

(From COE March 1973 Millers River Basin Water Supply Project)

Minimum flow downstream of Millers River Intake (above Athol)

January	100 cubic feet per second
February	100 cubic feet per second
March	100 cubic feet per second
April	250 cubic feet per second
May	250 cubic feet per second
June	250 cubic feet per second
July	400 cubic feet per second
August	200 cubic feet per second
September	150 cubic feet per second
October	150 cubic feet per second
November	150 cubic feet per second
December	100 cubic feet per second

TABLE 4

MILLERS RIVER WATER QUALITY

	NER W.Q. Studies 6/72[1] 12 Mo. R-5			Grab Samples[2]		EPA Drinking Water Regulations
	Min.	Mean.	Max.	7/11/78	8/29/78	
Arsenic			±0			0.05
Barium			±0			1.0
Cadmium			±0			0.010
Chromium			±0			0.05
Lead			±0			0.05
Mercury	0	0.002	0.004			0.002
Nitrate				1	0.1	10.0
Selenium			±0			0.01
Silver			±0			0.05
Fluoride			±0			2.0
Chlor. Hydro						0.0002-0.1
Chlorophenoxys						0.01-0.1
Turbidity	3	±17	70	5.7	2.0	1 TU
Coliform (Total)	1000	-	3160	9200	1100	1 per 100 ml
Coliform (Fecal)	63		1580	700	100	
D.O.	5.4	6.4	7.6	8.3	7.3	-
Chloride	7	±14	20	17	13	250
Color	20	±70	130	35	20	15 C.U.
Copper			±0			1
T.S.S.						
BOD_5				3.0	4.0	
Iron	1.0	± 0.3	0	3.0	0.6	0.3
Manganese	0	± 0.05	0.15			0.05
P (Total)	0.04	± 0.17	0.23	0.15	0.08	
pH				7.4	7.5	6.5-8.5
Sulfate						250 mg/1
TDS						500
Zinc	0	± 0.05	0.13			5
Sodium	0	±8	16			-
Hardness ($CaCO_3$)	10	±14	20			-
P (Total)						-
Aluminum			±0			-
Calcium						-
Total Alkalinity	2	±10	24	16	35	-

[1]NER, 1972 [2]Mass DEQE, 1978.

Table 4

1975 National Interim Primary and 1979 Secondary Drinking Water Standards.

The Millers River water fails to meet EPA Drinking Water Standards with respect to turbidity, coliform bacteria, color, iron, manganese, and possibly mercury.

There has been significant improvement in Millers River water in the past ten years. This trend appears to be indicated by the above data, even though the data are not sufficient to generate statistically-valid conclusions.

The improvement is primarily the result of treatment of water that had been previously discharged into the river as untreated municipal and industrial wastewater. The improvement was also implied during conversations with engineers from the Massachusetts Department of Environmental Quality Engineering (June 1980). A listing of the status of wastewater dischargers to the Millers River in 1970 and 1980 is shown in Table 5.

In spite of its deficiencies, Millers River water would be characterized as a good source for domestic raw water supply if adequately treated.

EPA Drinking Water Standards are applicable at the point of entry into the distribution system. Millers River water will undergo some natural treatment while in Quabbin Reservoir. However, the concerns expressed for the long term assimilative capacity of Quabbin Reservoir described for the Northfield Mountain alternative are also applicable to this alternative. Accordingly, a means of treatment was evaluated for this alternative to provide an indication of order-of-magnitude costs should treatment be required.

Operation

Under this alternative, flows in excess of the Millers River flow controls (see Table 3) would be withdrawn from the river when the Connecticut River was flowing above 17,000 cfs at Montague. The diversion would take place by raising a mechanical weir in the river and opening gates to an intake structure. The diverted water would drop down a Morning Glory intake and flow by gravity to Quabbin Reservoir. If required, ozone would be injected into the water in the shaft or initial reach of tunnel. After entering Quabbin Reservoir the water would mix with reservoir water and gradually migrate to the intake to the Quabbin-Wachusett tunnel.

The water quality of the river would be monitored on a daily basis during the flood skimming period and diversion would not begin, or would be stopped if already in

TABLE 5

Status of Wastewater Dischargers

WASTEWATER DISCHARGERS	1970[1,2] BELOW ATHOL	1980[2] BELOW ATHOL
Millers Falls Paper Co.	Untreated paper waste	Secondary waste treatment
Erving Paper Co.	Untreated paper waste	Secondary waste treatment
Millers Falls	Untreated municipal sewage	Secondary waste treatment
Erving	Untreated municipal sewage	Secondary waste treatment
Orange	Untreated municipal sewage	Secondary waste treatment
Athol	Partially treated municipal sewage	Partially treated domestic sewage, Secondary treatment by 1982
	ABOVE ATHOL	ABOVE ATHOL
South Royalston	Untreated municipal sewage	Secondary waste treatment
Baldwinville Paper Prod	Untreated paper waste	Tertiary treatment in summer, some problems in winter
Baldwinville	Untreated municipal sewage	Secondary waste treatment
Gardner	Secondary treatment but high ammonia nitrogen and phosphorus	Ammonia nitrogen eliminated, phosphorus still high
Winchendon	Primary treated sewage	Secondary waste treatment
Seaman Paper Products	No treatment	Secondary waste treatment

[1]USCOE, 1973

[2]Conversation DEQE, June, 1980, Kimball Simpson

progress, when water quality deficiencies exceeded predetermined standards. A similar facility may be necessary at the reservoir near the discharge point to monitor Quabbin Reservoir water quality.

Facilities

The facilities developed during the conceptual engineering study for the 70 mgd average annual diversion assumed for Phase I are shown in Figure 2 and briefly summarized below and later discussed in more detail.

- Water quality monitoring stations and laboratory;
- 200 foot long gated ogee crest weir;
- Slide gated intake control structure;
- If necessary, ozone injection equipment;
- 11 foot diameter Morning Glory intake shaft;
- 10 foot finished diameter concrete lined tunnel, 41,000 foot in length; and
- Outlet structure and channel.

Other intake and outlet locations and arrangements, water treatment facilities and tunnel alignments are possible and should be evaluated in subsequent phases. However, the above combination of facilities provides a reasonable basis for developing an order-of-magnitude cost estimate of the cost of delivering water via this alternative.

The facilities for this alternative were primarily developed from the designs shown in the COE Millers River Basin Water Supply Study (1973). A few minor changes were made. The major difference is a shift of the tunnel outlet from Gay Hill to Fairfield Hill in order to locate the outlet closer to lower reservoir levels.

Weir and Intake

The weir and intake structure are located on the Millers River about 1 mile above Athol. The weir location would be selected to minimize interference with natural river flows and flood stages. The center section of the weir, approximately 70 feet in length, would have gates which could be raised during flood flows and lowered during low flows. A gated control structure on the right abutment of the weir would control diversions to a Morning Glory intake shaft. The gates on this structure would be closed during low flows and open during flood skimming operations. Visual inspection of the site suggested that the right abutment would probably be in soil. Connection of the left

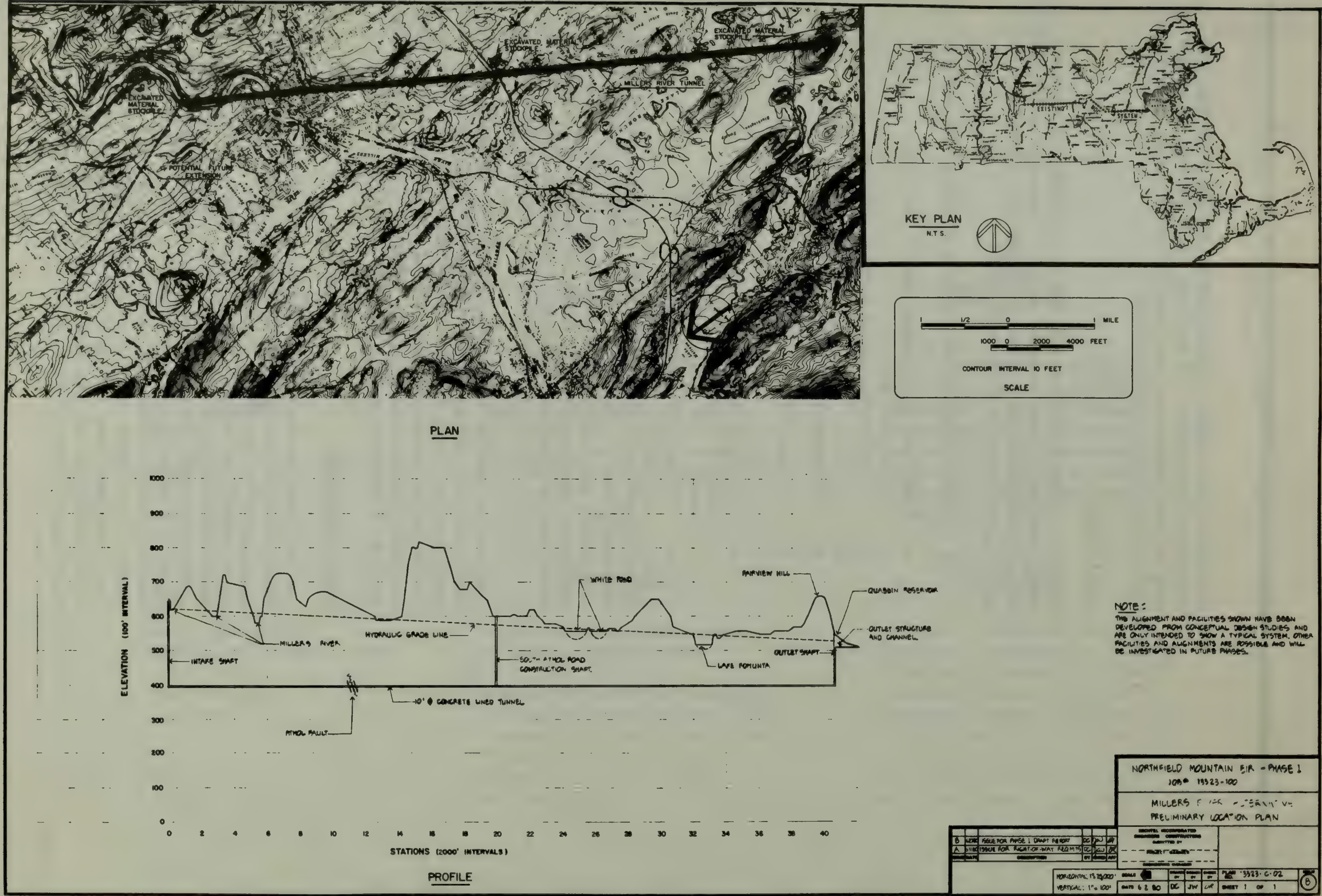


Figure 2

Originals at scale 1″ = 25,000′ are available for review at MDC or NCAC

abutment of the dam to the river bank and railroad embankment and alternative diversion facilities and arrangements should be evaluated in more detail in future phases.

Water Treatment

As discussed in the paragraph on water quality, some type of treatment may be required to complement the long term natural treatment process of Quabbin Reservoir. The Millers River water quality does not meet EPA drinking water standards for turbidity, coliform bacteria, color, iron, manganese and possibly mercury. For this study it appears that treatment with either chlorine or ozone would provide a satisfactory level of treatment.

Chlorine, however, has a number of detrimental side effects. In its inorganic aqueous forms, including chloramines, it is toxic to many species of desirable aquatic life at levels as low as 2 parts per billion. Moreover, chlorination of raw river water could result in formation of chlorinated organic compounds, some of which are suspected of potential carcinogens.

While all possible side effects of ozone have not been thoroughly investigated, it appears that it may be a safer choice than chlorine. However, additional studies are required to validate this tentative recommendation. Ozone treatment consists of two basic parameters - contact time and concentration. By increasing one the other can be reduced. It appears that, if the ozone were injected into the intake shaft and/or beginning of the tunnel and properly mixed, the tunnel would serve as a contact chamber and permit lower concentrations of zone. This possibility should be investigated in future phases.

Water Quality Monitoring

Water quality sampling stations were provided on the Millers River at the intake and near the outlet into Quabbin Reservoir. A certain standard of water quality would be required before any water would be diverted. A laboratory would be required; perhaps near the sampling station at Athol.

Tunnel

A 10 foot diameter reinforced concrete lined tunnel was selected for this phase to convey the diverted water from the intake structure to Quabbin. As shown on Figure 2, the tunnel alignment crosses under two bends in the Millers River, under the town of Athol, White Pond, and Lake Rohunta and crosses through one known fault, the Athol fault. Earlier studies and geologic investigations (COE, 1974, Ashenden, 1973) indicate that the tunnel would probably be located in sound rock along most of its length and could

probably be excavated by either a boring machine or conventional drill and blast methods. Supports would probably only be required when crossing the Athol fault. For this phase, it was assumed that the lining would need reinforcement to withstand one half of the internal pressure and that the rock would provide sufficient resistance to withstand the remaining pressure. In view of the possible competency of the rock over most of the tunnel length, this may be a conservative assumption and should be re-evaluated in the next phase. The potential for substituting shotcrete for concrete lining should also be evaluated in future phases.

Potential areas for disposing tunnel excavation are indicated on Figure 2. They were located, by inspection of topographic maps, to minimize interference with natural runoff and visual impacts. Investigations of potential sites and use of excavated materials would also be performed in future phases.

Outlet Structure and Channel

The outlet structure selected for this initial phase of the EIR study would consist of a reinforced concrete tunnel shaft access chamber and stilling basin. Gates would be located on the outlet of the access chamber to permit dewatering of the tunnel without lowering the water levels in Quabbin Reservoir. The stilling basin would dissipate high exit velocities which would develop during low reservoir water levels. An 800 foot long, 25 foot wide riprap protected channel would convey water from the outlet structure to a natural low channel in the reservoir. The location of the outlet structure will be dependent upon several factors:

- Potential requirements for full treatment prior to release to Quabbin Reservoir;
- The need to provide a channel from the outlet to a natural low flow channel to avoid disturbing bottom sediments and organisms; and
- Potential requirements to encourage natural mixing of diverted water with Quabbin Reservoir water.

These factors and alternative outlet arrangements need to be evaluated in more detail in subsequent phases.

Energy Requirements

Relatively little energy would be required to operate this alternative as the water would flow by gravity from the Millers River to Quabbin Reservoir. The only significant

power required would be for generation of ozone for water treatment. The energy requirement for this process would be approximately 5,000,000 kwh/yr.

UNRESOLVED ISSUES/ FUTURE STUDIES

Issues which need to be investigated in future phases of this study include the following:

- The COE reported the existence of "sludge banks" in the Millers River above Athol. The existence of these banks and estimate of potential impact on water quality at the time of potential skimming needs to be determined.
- Alternative intake structures, tunnel alignments, and outlet arrangements.
- Impacts of flood skimming on existing or planned downstream hydroelectric plants or other beneficial uses.
- Requirements for eliminating or reducing the entrance of undesirable fish or aquatic species into Quabbin Reservoir.
- The expected periods of flood skimming and impact on river stages.
- The location of suitable sites for depositing tunnel excavation.
- Short and long term water treatment requirements and methods.
- Projections of future water quality in the Millers River at Athol.

MERRIMACK RIVER

Background

The Merrimack River alternative was developed for this study from several schemes evaluated by the Corps of Engineers (COE) in their NEWS study of the Merrimack River Basin (USCOE, 1977). The COE study evaluated development of the Merrimack River as a source of future domestic water supply for communities within the basin and for export to the MDC system to meet 1990-2020 needs. The report concluded that a large regional system utilizing the Merrimack River was required to meet a 210 mgd shortage in eastern Massachusetts by the year 2020. Two techniques were evaluated for developing these diversion requirements, "continuous withdrawals" (year round diversion) and "high flow withdrawals" (flood skimming). Each would meet the 210 mgd requirement. The "continuous withdrawal" scheme required development of four reservoirs on tributaries of the Merrimack River within New Hampshire and appeared slightly more attractive economically. However, it was implied that the environmental impacts of the associated reservoir construction made this scheme less attractive than the "high flow withdrawal" scheme. For the 70 mgd flow augmentation objective of the EIR-Phase I study, the "high flow withdrawal" or flood skimming scheme was selected for development of conceptual layouts and order-of-magnitude cost estimates.

Yield

Although a precise value of safe yield for flood skimming from the Merrimack River was not found in the NEWS study, evaluation of average monthly flow data and permissible diversions during "low flow conditions" contained in the NEWS study indicated that a 70 mgd average annual diversion was possible. This conclusion is supported by the fact that this volume is less than 1/3 of that proposed for diversion in the NEWS study. Diversion would not, however, be possible during the entire year without interfering with other Merrimack River water resource needs. The COE study included an evaluation of the flow requirements related to water quality, hydroelectric power production, and the anadromous fish restoration program and developed the water resource flow requirements shown in Table 6. This Table indicates that diversions would only be possible during approximately a 200-day period from December through June. Accordingly, in order to develop an average annual diversion of 70 mgd, it would be necessary to divert about 125 mgd during these winter and spring months.

Water Quality

The United States Geological Survey (USGS) maintains a water quality monitoring station at the intake to the Lowell Water Treatment Plant, 2.7 miles upstream of the Pawtucket Dam. Water sampled from this location and analyzed by USGS provided the basis for selecting the

Table 6

Allied Water Resource Flow Needs* (cfs)
Merrimack River at Lowell, Massachusetts (USCOE, 1977)
Merrimack River Basin Water Supply Study)

Month	Water Quality	Existing Hydroelectric Power	Anadromous Fish Restoration Program	Average Monthly Flow
January	980	3,500	2,000	5,000
February	980	3,500	2,000	6,200
March	980	3,500	6,000	10,400
April	980	3,500	6,000	17,000
May	980	3,500	4,000	9,600
June	980	3,500	4,000	5,000
July	980	3,500	3,500	3,000
August	980	3,500	3,500	2,400
September	980	3,500	3,500	2,200
October	980	3,500	3,500	3,000
November	980	3,500	3,500	3,000
December	980	3,500	2,000	5,400

"*Note: figures shown are flow rates considered satisfactory for purposes shown. The values presented, however, are not additive. For example, a flow rate of 6,000 cfs in March would satisfy not only the anadromous fish program requirements but those also for water quality and hydroelectric power."

water treatment processes for this study. Data obtained for this location are tabulated in Table 7. Also shown in Table 7 are the Environmental Protection Agency (EPA) National Primary and Secondary Drinking Water Standards.

Evaluation of Merrimack River water quality indicates that the following parameters may not meet EPA Drinking Water Standards: turbidity, coliform bacteria, color, iron, manganese, and possibly cadmium and pH. Comparison of the early 1970's and late 1970's data indicates a trend of improvement in water quality in the past ten years. In general, Merrimack River water at this location would be characterized as fair for purposes of domestic/raw water supply. It is capable of being upgraded to excellent drinking water quality through the use of proven water treatment techniques.

Operation

Under the Merrimack River alternative, water would be withdrawn from the river near Tyngsboro whenever river flows exceeded the flow controls in Table 6. The water would be treated to make it suitable for domestic consumption, conveyed to Shaft 9A of the MDC tunnel system in Medford and delivered to user communities in the northern portion of the MDC system via existing MDC facilities. This water would replace water normally released from the Quabbin-Wachusett Reservoirs. During periods when Merrimack River flows were below the established flow controls, no withdrawals would be made and deliveries from the Quabbin-Wachusett system would be resumed.

Facilities

The facilities developed during the conceptual engineering layouts for an average annual yield of 70 mgd are shown in Figure 3, briefly summarized below and later discussed in more detail.

- Intake structure - 125 mgd capacity reinforced concrete structure;
- 125 mgd water treatment plant;
- 12,600 Hp pumping plant;
- 72 inch diameter pipeline 29 miles long; and
- pipeline appurtenances.

Other intake locations, pipeline alignments, water treatment plant processes, combinations of pipeline diameter and pump plant capacity and transient protection systems are possible and should be evaluated in subsequent phases. However, the above combination of facilities provides a

TABLE 7

SUMMARY OF MERRIMACK RIVER WATER QUALITY

AT LOWELL

U.S.G.S. SAMPLING STATION 1

	1969 - 1972 (1)			1973 Monthly Composites (1)			1977 - 1978 Monthly Samples (2)			EPA Drinking Water Standards
	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	
Arsenic	0	.0014	.007				0	0.0013	0.003	0.05
Barium	0.01	0.015	0.018				0	0	0	1.0
Cadmium	0	0.012	0.030				0	0.0013	0.004	0.01
Chromium	0	0.005	0.011				<0.010	0.020	.040	0.05
Lead	0.004	0.0095	0.013				0.005	0.009	0.014	0.05
Mercury	0.0001	0.0006	0.0012				<0.0005	<0.0005	<0.0005	0.002
Nitrate (asn)	0.09	0.511	2.7	0.9	2.3	9.7	0.20	0.30	0.55	10.0
Selenium							0	0	0	0.01
Silver	.0006	.00019	.0003				0	0	0	0.05
Fluoride	0.3	0.4	0.5	0.2	0.3	0.8	0	0.1	0.2	2.0
Chlor. Hydrocarb	0	0	0				0	0	0	0.0002 - 0.1
Chlorophenoxys	0	0	0				0	0	0	0.01 - 0.1
Turbidity	0.9	5.13	30.0	1	3	4	1	2.7	5	1 TU
Coliform (Total)	3200	42127	260000				1400	24363	80000	1/100 ml
Coliform (Fecal)				2400	812	250	120	913	2200	
DO				5.2	9.5	13.8	7.4	11.5	14.1	-
Chloride				5.0	12	19.0	24	14.2	8.7	250
Color	25	33.75	50							15 c.u.
Copper	0	0.013	0.020				0.004	0.007	0.017	1.0
Corrosivity										Non-Corr.
Foaming Agents										0.5
Iron	0.20	0.276	0.420				0.260	0.413	0.630	0.3
Manganese	0.040	0.060	0.070				0.040	0.057	0.090	0.05
Odor										3 T.O.N.
pH				6.3	6.8	7.2	6.4	6.6	7.2	6.5 - 8.5
Sulfate				5.5	8	11.0	7.4	10.5	18	250
TDS	67	77	87	27	48	71	36	54.5	85	500
Zinc	0	.042	0.140				0.010	0.019	0.040	5
Sodium				3.8	8.4	13	6.6	10.3	18	-
Hardness ($CaCO_3$)				12	16	22	1	4.8	8	-
Silica				4.6	5.2	6.3	2.8	5.3	9.8	-
Aluminum										-
Calcium				3.7	5.1	6.9				-
Total Alkalinity				4	7	11	7	11.4	18	-

Units are mg/l unless otherwise stated.

(1) Hayden, 1975
(2) USGS, n.d.

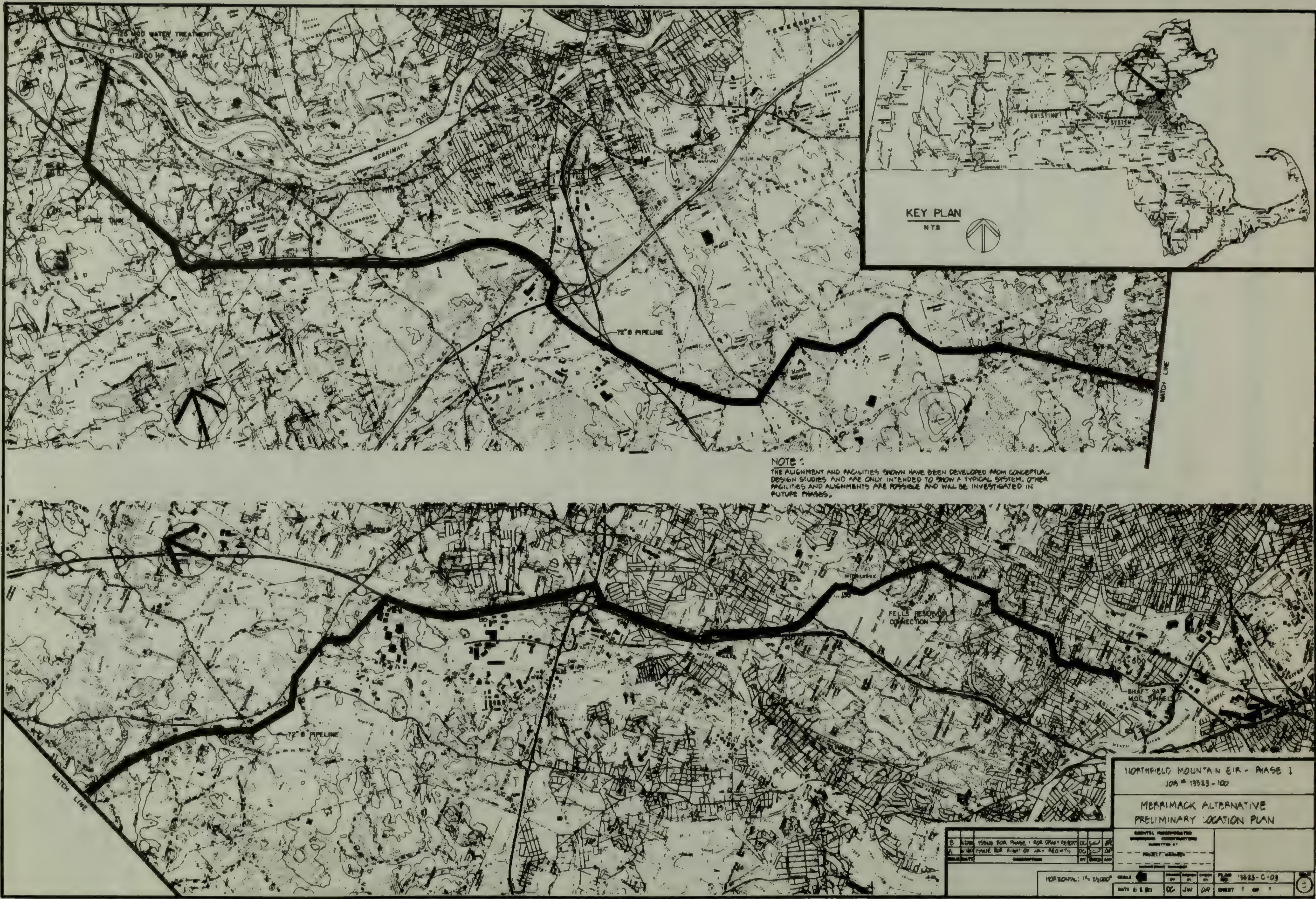


Figure 3

Originals at scale 1" = 25,000' are available for review at MDC or NCAC

reasonable basis for developing an order-of-magnitude estimate of the cost of delivering water via this alternative.

In the NEWS study, a 12 foot diameter 36 mile long tunnel was selected to deliver the water to Shaft 9A and the Norumbega Reservoir. This difference in schemes is primarily due to the much larger 210 mgd yield developed for the NEWS study.

Intake Structure

A potential intake structure location would be 1 mile downstream of Tyngsboro on the south bank of the river. For this EIR study, a smaller but similar structure to that developed in the NEWS study was selected. This structure would be sized and located to minimize disturbance to game fish, spawning activities, and fish eggs and protected from high river flood flows and stages.

A typical intake works would consist of the following:

- Fixed bar screen - Bar spacing of about 3 inches in order to remove large debris;
- Travelling screen - Openings of 1/4 to 3/8 inch to eliminate smaller debris;
- Sump - Large tank from which raw water pumps withdraw water;
- Raw water pumps - Six, each rated at 30 mgd; and
- Flow control and monitoring - venturi meters with automatic pump control.

Water Treatment Plant. A method of treatment was tentatively selected by Bechtel, Inc. to treat the water quality parameters in Table 7 which did not meet EPA drinking water standards i.e., turbidity, coliform bacteria, color, iron, manganese, cadmium and pH. The unit processes selected for this study are briefly described below. These processes are typical of those which would be used to treat water similar to Merrimack River water. Other combinations of treatment processes are available and would be considered during final design studies to select the most efficient treatment process.

Chemical Addition. Chemicals added would be ozone for oxidation of iron and manganese and removal of tastes and odors, alum for coagulation, lime for pH adjustment, and chlorine for oxidation and disinfection.

Rapid Mixing. Rapid mixing results in the dispersion of chemicals throughout the water to be treated. Detention time in the mixing basin would be approximately 60 seconds.

Coagulation/Flocculation. Coagulation is the driving together of colloidal particles by chemical forces. Flocculation is the coalescing of coagulated particles into flox particles through gentle agitation. The flow-through velocity of the coagulation/flocculation basins would be on the order of 1 foot per second with a detention time of between 20 and 60 minutes.

Sedimentation. This process uses large basins to bring the water to a quiescent state to reduce the amount of suspended solids in the water. Typical design criteria would be a surface loading rate of 800 gallons per day per square foot of surface area; detention time of 4 hours and overflow rate of less than 20,000 gallons per day per foot of weir length. Mechanical sludge scrapers would be provided to direct the settled material to an outlet.

Ozone Contact. Ozone contact would be used to remove taste, odor, color and soluble metals. The ozone contact time would be approximately 5 minutes.

Filtration. Water filtration is a physical/chemical process for separating suspended and colloidal impurities from water by passage through a porous medium, usually a bed of sand or other granular material. For this study, a surface loading rate of 5 gallons per minute per square foot was used.

Carbon Contact. Granular activated carbon would be provided to absorb natural and synthetic organic chemicals in order to reduce taste and odor problems and potentially serious health effects of the organic chemicals. Regulations proposed by EPA in February 1978 would require that community water systems with populations greater than 75,000 people use granular activated carbon in their drinking water treatment systems. Experiences at Lowell and Lawrence (downstream of the potential site) indicate that traditional treatment may not be sufficient to attain the highest quality effluent. Lawrence has installed activated carbon in their sand filters and Lowell proposed (or has) installation of granular carbon filters during its plant expansions. In their report for the COE on treatment facilities for the Merrimack River, Hayden, Harding & Buchanan recommended granular activated carbon contact (Hayden, 1975). That recommendation was adopted for this EIR study.

Loading rate for a carbon contactor would be approximately 5 gallons per minute per square foot.

Clear Well Storage. Treated effluent would be pumped to storage in a clear well. The function of the clear well for this plant would be to allow a ready reserve of finished water and to provide a sump for the high service pumps. Sufficient clear well capacity would be provided to store or release incremental differences in the flow rates of the treatment plant and high service pumps.

Disinfection. For purposes of this study, it was assumed that disinfection by post chlorination would be provided by the MDC at the point of delivery to the user community via existing facilities. Chlorine residuals from prechlorination would be about 1 milligram per litre (mg/l) in the treated effluent.

Sludge Handling. In the treatment process described above, sludge would be generated through sedimentation and by the filter backwash operations. Waste water from each operation would be transferred to thickening tanks and residual sludge would be trucked off-site for final disposal. A flowsheet of the above described process is shown in Figure 4.

Pumping Plant. A pumping plant would be required to lift the treated water from elevation 90 at the treatment plant to elevation 271 required by the MDC system at Shaft 9A and to provide for friction losses in the conveyance pipeline. Five 22,000 gpm pumps and five 3,150 Hp pump/motor units were selected for this facility. One unit is an installed standby and would only be used in the event of failure of one of the other four units. The units would be enclosed in a pump house. Power was assumed available at Chelmsford and a 13.8 Kv line from the plant to the Chelmsford switchyard was included for this alternative.

Pipeline. A 72 inch diameter prestressed concrete pipe was selected to convey treated water from the treatment plant to Shaft 9A. Concrete appears to have the best combination of properties for the expected trenching conditions, size and pressure, but other materials would be evaluated in future studies. The pipe size was selected on the basis of judgement of economic tradeoffs between pipe size and pumping power. A smaller pipe would require a larger pump plant and higher annual energy costs and vice versa. A study of the most economical size should be performed in future studies to obtain the most advantageous balance between capital and operating costs. The pipeline alignment was selected to minimize disturbance of existing infrastructure and urban communities without excessively deviating from the shortest practical route to Shaft 9A. A brief field inspection of the proposed alignment indicated that the pipeline would still have significant urban contact and environmental impacts and substantial portions of the pipeline trench would be constructed in rock or swamp. Detailed alignment surveys

FIGURE 4

SCHEMATIC FLOWSHEET
MERRIMACK RIVER WATER FILTRATION PLANT

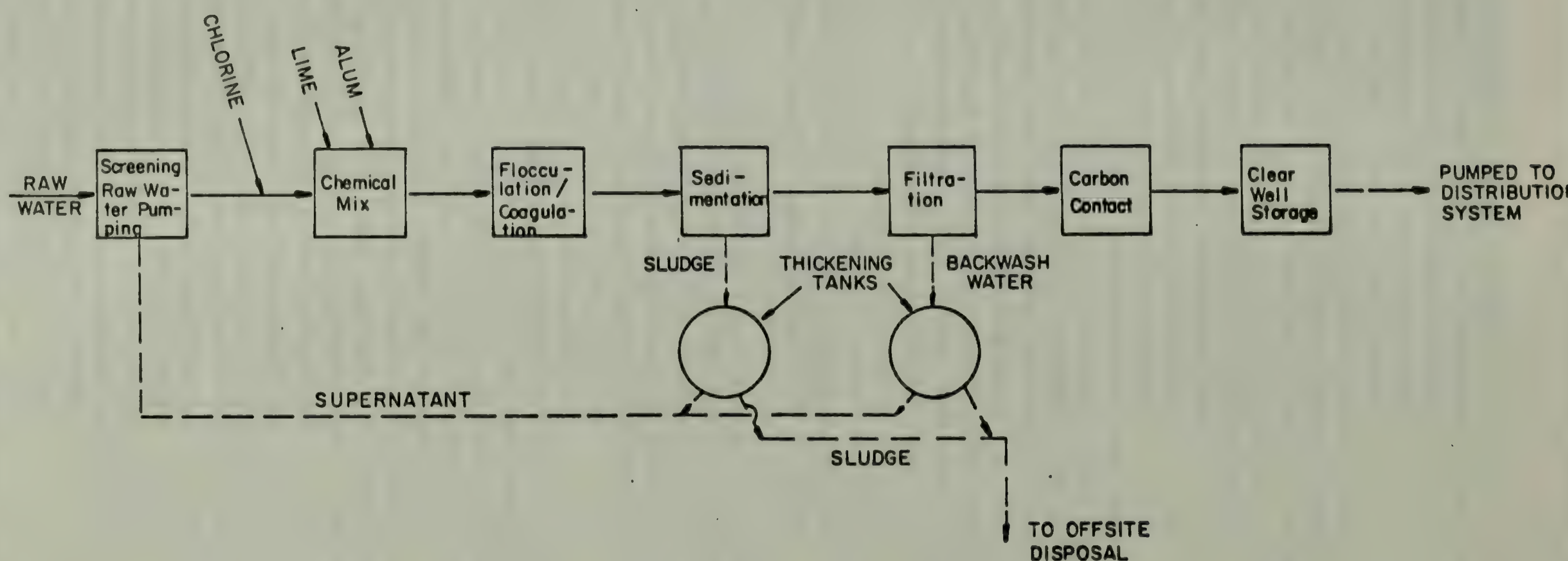


Figure 4

and studies should be performed in future studies to obtain the best combination of cost and environmental impacts. The proposed alignment should provide for this phase of the EIR, a reasonable basis for determining an order-of-magnitude cost estimate. A stand pipe was provided near the beginning of the pipeline to control transient pressures during sudden pump plant shutdowns. This method of control is reliable but in this case expensive because of the distance from the pipeline to a suitable pipe stand location. Other measures, such as air pressure vessels, inlet valves, and slow closing check valves may be more cost-effective and should be evaluated in future studies.

Energy Requirements

Substantial amounts of energy will be required to operate the pumps and equipment in the water treatment plant, to produce ozone, and to pump the water from the treatment plant to Shaft 9A. The estimated energy requirements are summarized below:

- Water Treatment Plant - Equipment and ozone production

  Electricity - 19,000,000 kwh/year
  Natural Gas - 12,000,000 SCF/year;

- Conveyance Pump Plant

  Electricity - 44,000,000 kwh/year.

UNRESOLVED ISSUES/FUTURE STUDIES

Issues which need to be investigated in future phases of this EIR study for the Merrimack River alternative include the following:

- Alternative intake points, structure selection and arrangement, optional water treatment processes, pipeline alignments and sizes, points of connection to the MDC system.

- Required modifications to the MDC system to accept the developed supply.

- Impact of the flood skimming on existing or planned downstream hydroelectric production or other beneficial uses.

- Integration of the diversion facilities with other regional or Merrimack Basin water supply plans.

- Impact of future energy cost increases on annual costs.

- Evaluation of river hydrographs to forecast duration, period and potential amounts of flood skimming during normal and drought years.

- Collection of additional Merrimack River water quality data and projections of water quality trends.

UPPER SUDBURY

Background

Since the late nineteenth century, the Sudbury Reservoir has played a role in Boston's water supply. Upon its completion in 1896, it became a principal source of domestic water for the Boston metropolitan area. As other sources of supply were developed, Sudbury Reservoir was gradually withdrawn from service due to the availability of superior quality water from the new sources. Since then, Sudbury Reservoir has been used primarily to supplement supplies to the Metropolitan District Commission's (MDC) system in periods of drought or extremely high peak demands. Since the drought of the mid-to-late nineteen sixties, increasing attention has been focused upon the reactivation of the Sudbury watershed to augment MDC water supplies. A map of the watershed is shown in Figure 5.

In 1975, a study of the upper Sudbury watershed was performed for the MDC (Maguire, 1975). This study investigated feasibility of development of the entire Upper Sudbury system including Sudbury Reservoir, Framingham Reservoirs 1, 2 and 3, and contributing watersheds. The study produced four alternative water resource allocation plans for the 75.2 square mile drainage area of the Upper Sudbury River watershed shown in Figure 5.

In 1979, a fifth water resource allocation plan was investigated (Maguire, 1979). This plan considered only the 22.3 square mile drainage area tributary to Sudbury Reservoir. On Figure 5 this is approximately the shaded area around the Sudbury Reservoir. These two reports are the source for most of the information provided below.

Description of Alternatives Presented in the 1975 and 1979 Reports

Upper Sudbury River Basin Watershed Plan. In the 1975 study, Allocation Plan C (45 MGD) had the most favorable benefit/cost ratio but only Allocation Plan B (29 MGD) was mentioned in the "Summary and Conclusions". The Summary and Conclusions" also states "More water is available under other alternative water resource allocation plans but more effect would be felt downstream." Except for this statement, no other basis for selection of Allocation B over Allocation Plan C was found in the brief period available to review the study in this phase. (The updated costs of the four allocation plans presented in the 1979 study also showed Allocation Plan C to be more favorable than Allocation Plan B).

Allocation Plan C was adopted for this phase of the EIR since it appeared to develop the maximum yield of the source (which is consistent with the methodology developed for this phase) and also appeared to have a favorable benefit/cost ratio. The potential environmental impacts

Figure 5

From "A Study of the Upper Sudbury Watershed" by C.E. Maguire Inc.; 1975

of Allocation Plan C will be evaluated in future phases on the same basis as the other alternatives.

In the 1975 study Allocation Plan C utilized the full 75.2 square mile Upper Sudbury watershed. This plan required construction of a 125 mgd water treatment facility near the Sudbury Reservoir Dam, a 250 mgd pumping station in the vicinity of Framingham Reservoir Dam No. 1, and two parallel 60 inch diameter transmission pipelines from the pumping station to Sudbury Reservoir. During high-flow periods, water would be pumped from Framingham Reservoir Dam No. 1 to the Sudbury Reservoir. Raw water would then be withdrawn from Sudbury Reservoir, treated, and discharged by gravity to the Weston Aqueduct. The treatment process recommended in the 1975 study was microstraining and ozonation. A schematic of the features of this plan is shown in Figure 6.

Sudbury Reservoir Watershed Plan. The 1979 study introduced a fifth alternative called "Allocation Plan E". This plan considered utilization of the 22 square mile watershed contributing to Sudbury Reservoir. On the basis of highest benefit/cost ratio, Allocation Plan E was the construction of a 30 mgd water treatment plant on MDC owned land near the Sudbury Reservoir Dam. This facility would process 21.9 mgd during an average runoff year. Treated water suitable for domestic use would be delivered to the Weston Aqueduct by gravity.

The treatment process proposed in the 1979 study for Allocation Plan E was chemical addition, rapid mixing, flocculation, sedimentation and filtration. The micro-straining and ozonation process recommended in 1975 was deleted.

The method proposed for filtration was low-head, automatic backwash. Advantages presently claimed for this process are low terminal head loss, simpler valve and piping systems, and lower operation and maintenance costs. This mode of filtration has been successfully used in installations in New England. Prior to the use of this filtration method a detailed evaluation of the technical acceptability and costs of several existing installations should be performed, particularly for installations in the 30 mgd size range.

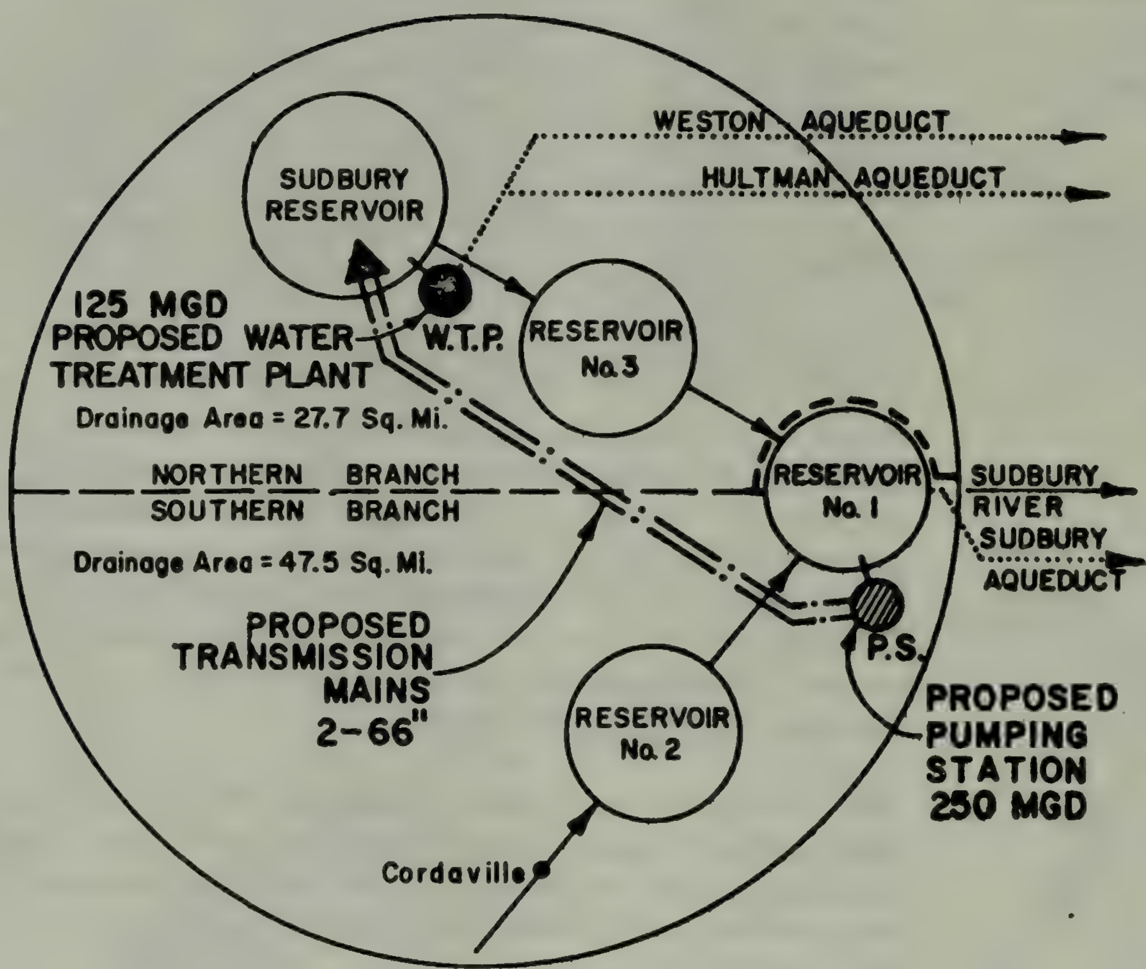


Figure 6

Schematic of Allocation Plan "C"

From "A Study of the Upper Sudbury Watershed" by C.E. Maguire Inc.; 1975.

Yield

The yields reported in the 1975 and 1979 studies are summarized below:

- Allocation Plan C (1975) - 45 mgd
- Allocation Plan E (1979) - 21.9 mgd

The yields appear to represent a year of average runoff and are referred to in the studies as "average annual water produced".

Water Quality

Water quality data are summarized in Table 8. Also shown are Environmental Protection Agency (EPA) 1975 National Interim Primary and 1979 Secondary Drinking Water Standards.

Comparison of Sudbury Reservoir water quality parameters with EPA Standards indicates that treatment is necessary for coliform bacteria, turbidity and color. Taste and odor, while not regulated by EPA, are also known to be a recurrent complaint with regard to Sudbury Reservoir water. However, a good-to-excellent source of raw water for domestic supply.

Energy Requirements

Estimates of the energy required to operate the water treatment plant processes and pump plant for the two options considered under this alternative were not found in the existing reports.

For comparison purposes in this Phase I study, an energy estimate was developed. Lacking specific information on pumping requirements and treatment processes, this estimate of energy requirements is approximate and should be refined in future phases.

Approximate energy requirements are summarized below:

- Upper Sudbury Reservoir Watershed

Water Treatment Processes and Equipment:	2,300,000 kwh/yr

- Upper Sudbury River Watershed (45 mgd)

Water Treatment Processes and Equipment:	5,000,000 kwh/yr
Pump Plant	4,000,000 kwh/yr
Total	9,000,000 kwh/yr

TABLE 8

UPPER SUDBURY RIVER WATER QUALITY DATA

(Maguire 1975 and 1979)

Sample Location & Date / Parameter	Framingham Reservoir No. 3 - Avg. of Tests 1965-73	Sudbury Reservoir No. 1 - 1972 Mean	Min	Max	Sudbury Reservoir #1 (Maguire Subs) November 1978	Sudbury Reservoir #1 1978 Avg. MDC	EPA Regulations Drinking Water
Arsenic	0.001				< 0.005	< 0.005	0.05
Barium	-				< 0.100	-	1.0
Cadmium	-				< 0.005	< 0.005	0.01
Chromium	-				< 0.005	< 0.005	0.05
Lead	-					< 0.005	0.05
Mercury	-				< 0.002	< 0.002	0.002
Nitrate (asn)	0.24				< 0.04	0.03	10.00
Selenium	-				< 0.005		0.01
Silver	-				< 0.005	< 0.005	0.05
Fluoride	0.06				< 0.12	< 0.06	2.0
Chlorinated Hydrocarbons	-				0		0.0002-0.1
Chlorophenoxys	-				0		0.01-0.1
Turbidity	1.5 JTU	2 JTU	1 JTU	4 JTU	< 1.4	1.3	1 TU
Coliforms (Total)						4 per 100 ml	1/100 ml
Coliforms (Fecal)							-
DO	-					9.9 (78%)	-
Chloride	38	50	35	82 (Winter)		23.0	250
Color	2.2 color units	~55	23 c.u.	100 color units	< 40	24	15 color units
Copper	0.07					< 0.02	1.0
Corrosivity	-						Non Corr.
Foaming Agents	-						0.5
Iron	0.08					0.23	0.3
Manganese	0					< 0.02	0.05
Odor	-						3 T.O.N.
pH	-					6.8	6.5-8.5
Sulfate	13.4					12.0	250
TDS	-						500
Zinc	-					< 0.02	5
Sodium	27.4					14.4	-
Hardness ($CaCO_3$)		40	30	50		27	-
Silica						2.9	-
Aluminum						0.04	-
Calcium						7.2	-
Total Alkalinity						12.0	-

Units are mg/1 unless otherwise stated.

UNRESOLVED ISSUES/FUTURE STUDIES

Issues that need to be investigated in future phases of this study include the following:

- The existing Sudbury Dam intake works would be used as a treatment plant intake. What costs are required, if any, to modify/rehabilitate this facility?
- Will granular activated carbon contact be required to satisfy potential EPA regulations?
- Potential elimination of pretreatment requirements.
- Projections of future Sudbury Reservoir water quality.
- What controls will be imposed on reservoir levels and releases and what would be the impact on yield and treatment costs?
- Additional analysis of proposed treatment processes and related projected capital and operating costs.

LOCAL SOURCES
ABANDONED/RESERVE SUPPLIES

Background

A report entitled "Abandoned or Reserve Water Supplies - Metropolitan District Commission Service Area" was prepared in February 1980 by Coffin & Richardson, Inc. under contract with the Department of the Army, Corps of Engineers, New England Division. The purpose of this report was to determine the potential feasibility of reactivating abandoned or reserve sources of water supply within the 44 communities supplied by the MDC.

The objectives of the report were stated as follows:

"a) To identify water supplies that have been abandoned or that have been placed in reserve with a yield of greater than 100 gallons per minute (GPM) and located within the area supplied by the Metropolitan District Commission (MDC).

b) To collect basic data on, and make site inspections of all the identified supplies in order to compile a fact sheet on each supply.

c) To determine which, if any, of the identified supplies are potentially feasible to reactivate.

d) To determine to the extent available data permits, the methods of water treatment necessary to reactivate those supplies found to be potentially feasible.

e) To prepare order-of-magnitude estimates of the cost of reactivation for those supplies found to be potentially feasible.

f) To determine which, if any, of the supplies found to be potentially feasible are practical to reactivate based on estimated cost, environmental constraints and downstream flow requirements." (Coffin & Richardson, 1980)

Forty-six (46) abandoned or reserve water supplies were identified and evaluated during this study.

The feasibility of reactivation of each of the identified sources was evaluated according to the following criteria:

"A source would not be potentially feasible if,

a) Reactivation of the supply would require extensive relocation or destruction of existing surface structures.

b) Reactivation of the supply could not be accomplished if desalinization procedures were employed.

c) Reactivation of the supply would reduce the yield of other water supplies presently in use.

d) Leachate from a sanitary landfill or other solid waste disposal facility would be likely to enter the supply.

e) Other forms of water quality degradation have rendered the supply unfit for use as a public water supply." (Coffin & Richardson, 1980)

In addition to the feasibility criteria, an analysis of the economic practicality of each potentially feasible water supply was made by estimating the cost of water per million gallons. A cut-off point of $480 per million gallons per year was chosen to separate "practical" supplies (those below $480) from the "impractical" supplies (those above $480). The $480 figure was chosen because it is exactly twice the present rate charged for water by the MDC. No stated rationale was provided for the use of twice the present MDC rate as a basis for determining economic feasibility of source development. This economic criterion was critical to the exclusion of 25% of the sources from reactivation (see Table 9). These sources should be re-evaluated when the annual costs of supply of alternative sources exceeds this criterion.

For several surface supplies for which yield data was unavailable, estimates of yield were made from curves found in the <u>Third Progress Report of the Committee on Rainfall and Yield of Watersheds in New England</u> in the Journal of the New England Water Works Association, Volume 59, September 1945. This source seems to be inadequate for making valid predictions in 1980. During the period from 1945 to 1980 significant changes may have been made to the recharge areas and watersheds which could result in substantial alterations in the yield of those sources. In addition, some of the water quality data was obtained 30 years ago and comprehensive evaluations of downstream flow requirements were not made.

In the study, the following qualification was included, which emphasizes the tentative nature of estimates of the magnitude of yield potentials:

> "It should be kept in mind that the designation of a water supply as being practical for reactivation should only be interpreted to mean practical within the context of this study. Since this study is primarily concerned with gathering general information on a large number

TABLE 9

Potential Sources for Industrial Water Supplies
(Rejected as Domestic Source on Basis of Cost) Coffin & Richardson, 1980

Source Name	Reasons for Rejection (Other than Cost)	Yield (MGD)	Reactivation Cost (X $1000)
Great Meadows - Lexington	None	1.00	1,335
Springdale Supply - South Canton and North Stoughton	None	0.70	1,430
Wekepee Brook Supply - Sterling	None	1.20	4,000
Farm Pond - Framington	None	0.70	2,250
Williams Lake - Marlborough	None	See Millham Reservoir	See Millham Reservoir
Millham Reservoir - Marlborough	None	2.2	7,250
Spot Pond Auxiliary Supply - Medford	None None	0.22	660
Cold Harbor Brook Reservoir - Shrewsbury	None	0.18	600
Ellis Station Supply - Norwood	None	2.50	2,710
Pine Street and Johnson Street Wells - Peabody	None	1.20	1,530
*Cedar Pond - Peabody	-	1.80	-
*Old Quincy Reservoir - Quincy	-	1.00	-
Leaping Well Reservoir - South Hadley	None	0.28	700

*In use as an Industrial supply.

> of water supplies rather than providing an in-depth analysis of an individual supply, it is entirely possible that a more detailed study of any of the supplies identified in this report as being practical could turn up information causing that supply to be rejected as impractical. The water supplies identified in this report as being practical should be considered only as being the best candidates for further study concerning possible reactivation." (Coffin & Richardson, 1980)

Yield

The study found twenty-one (21) supplies "potentially feasible" to reactivate. Of these, nine supplies were found "practical" to reactivate. Included in these "practical" supplies was the Sudbury Reservoir which is covered as a separate alternative in the EIR Phase I study. The eight remaining supplies which this study (Coffin & Richardson, 1980) identified as "practical" to reactivate have a combined potential yield of 31 mgd. Emphasis has been placed on the word "potential" due to the limitations discussed above on the data gathering and evaluation effort. For example, while the above discussion suggests that the potential yield of reactivating abandoned supplies might be less than 31 mgd, there are possibilities for developing useable supplies from these sources. If the high cost of development was primarily due to the treatment required to make the source suitable for domestic use, it might be possible to find an industry in the immediate source area that could use a lower quality of water and replace their potable demands with this supply. Further, the 100 gpm lower limit on supplies considered for investigation and the $480/million gallons value used to determine "practicality of reactivation" need to be reviewed in future phases. It appears that the $480/million gallons economic limit was applied to about thirteen of the sources evaluated in the study (see Table 9).

Water Quality

A summary of the water quality data for the eight sources found to be "practical to reactivate" (Coffin & Richardson, 1980) is shown in Table 10. Copies of the fact sheets developed for the study are in the Appendix. The years in which the water quality sampling and testing were performed is also noted in Table 10. Some of the data is over thirty-years old and may not reflect the present water quality of the source. Asterisks indicate those parameters exceeding EPA National Interim Primary Drinking Water Standards (*), and those exceeding EPA National Secondary Drinking Water Standards of 1979 (**). EPA Primary and Secondary Drinking Water Standards are listed in Tables 11 and 12 respectively. The Upper Sudbury River is

TABLE 10

Summary of Water Quality Data for Abandoned or Reserve Water Supplies
Which Were Found Practical To Reactivate (1)
(Coffin & Richardson, 1980)

	Dedham Avenue Supply - Needham	Newton Water Works - Needham and Newton (2)	Charles River Wells - Waltham (2)	Rosemary Brook -Wellesley	Chicopee River Canal - Chicopee	Cooley Brook and Morton Brook Reservoir -Chicopee	Lake Cochituate Wells -Framingham	Buckmaster Pond -Westwood
Year of Analysis	1971	1953	1949	1979	1978	1949	1968	1975
No. of Samples	3	3	2		4	3	3	
pH	6.3	6.4	6.5	7.2	7.4	6.7	6.8	7.3
Alkalinity (Total $CaCo_3$)	16	33	65	47	19	17 ppm	53	54
Hardness ($CaCo_3$)	74	52	52	82		22 ppm	101	80
Suspended Solids					5.3			
Total Solids					88.5			
Odor	0			0				0
Color	0	3	18**	0	36**	34**	5	40**
Turbidity	0			.5	1.3*			11*
Sediment	0			0				0
Total Nitrogen					1.47			
Ammonia Nitrogen	.02			.06	.04	.031 ppm		.02
Nitrate Nitrogen	4.7	.50	.14	1.6	.25	.43 ppm	0.1	.5
Nitrite Nitrogen	.001		.003	0				.017
Albuminoid Ammonia						.124 ppm		
Total Phosphorus					.11			
Oil & Grease					1.4			
Calcium (Ca)				24				27
Chromium (Cr)					0			
Cadmium (Cd)					0			
Potassium (K)				1.4				2.5
Mercury (Hg)					0			
Lead (Pb)					0			
Magnesium (Mg)				53				3.2
Manganese (Mn)	0		.75**	.03			0.52**	.13
Silica (SiO_2)				13				7.3
Sulfate (SO_4)				23				22
Chloride	51	11	9	43	15	2.7 ppm	20	76
Nickel (Ni)					0			
Copper (,				.49	.01			0
Iron (Fe)	.01	.04	3.8**	.19	.65**	.23 ppm	.13	1.5**
Sodium (Na)	22			25				60
Specific conductivity (micromhos/cm)				290				360
Zinc (Zn)					0			

(1)Values are reported in Milligrams per liter for concentrations of chemical elements and compounds unless stated otherwise.
(2)Worst set of water quality values stated (where more than one set of tests were reported).

*Fails to meet EPA Interim Primary Drinking Water Standards
**Fails to meet EPA Secondary Drinking Water Standards

TABLE 11

National Interim Primary Drinking Water Standards - 1975 [1]

Contaminant	Level
Arsenic	0.05 mg/l
Barium	1.0 mg/l
Cadmium	0.010 mg/l
Chromium	0.05 mg/l
Lead	0.05 mg/l
Mercury	0.002 mg/l
Nitrate (as N)	10.00 mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l
Fluoride	2.0 mg/l
Chlorinated Hydrocarbons	0.0002 - 0.1
Chlorophenoxys	0.01 - 0.1
Turbidity	1 TU
Coliform	1 per 100 ml

TABLE 12

National Secondary Drinking Water Standards - 1979 [2]

Contaminant	Level
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corrosivity	Non corrosive
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor number
pH	6.5 - 8.5
Sulfate	250 mg/l
TDS	500 mg/l
Zinc	5 mg/l

[1] Federal Register, 1975

[2] Federal Register, 1979

excluded from this data summary since this abandoned source was discussed as an alternative earlier in this report.

A summary of water quality deficiency, yield and treatment processes proposed for each abandoned source is given in Table 13, with comments on the acceptability of the treatment process for the levels on contaminants to be removed. The recommended water treatment processes and conclusions on the feasibility of treatment will need to be reconfirmed after extensive sampling and analysis has been conducted on the abandoned supplies to detect new contaminants or higher levels of contamination which may require special treatment.

Facilities

The abandoned and reserve sources identified as "potentially suitable for reactivation" in the study (Coffin & Richardson, 1980) consist of wells and surface canals and reservoirs. The facilities required for reactivation varied for each source, but primarily consisted of water treatment plants, pumps, and pipeline connections. Details of each are included in the Appendix.

Energy Requirements

The report (Coffin & Richardson, 1980) did not include an estimate of energy requirements for operating the abandoned or reserve water supply sources.

For comparison purposes, an order-of-magnitude estimate was developed for the EIR Phase I study. Due to lack of specific information on pumping requirements and treatment processes, the estimate of energy requirements is approximate and should be refined in future phases.

Approximate energy requirements are summarized below:

Treatment Processes & Equipment:

Electricity -	11,000,000 kwh/yr
Natural Gas -	3,000,000 scf/yr

Well & Conveyance Pumps:

Electricity -	8,000,000 kwh/yr

TABLE 13

Water Treatment Processes

Source Name	Yield MGD	Water Quality Parameter Requiring Treatment	Type of Supply	Treatment Recommended for Reactivation	Comments on Treatment Process Proposed
Dedham Avenue -Needham	0.43	None	Groundwater & Surface	Chlorination	Satisfactory, however taste and odor should be investigated
Newton Water Works -Needham & Newton	8.00	Odor, Taste, Color	Groundwater	Chlorination, Coagulation, Sedimentation, Filtration	Satisfactory, however provision should be made for powdered activated carbon for T&O control.
Charles River Wells -Waltham	3.00	Color, Iron, Manganese	Groundwater	Chlorination, Iron Removal	Filtration will probably be required
Rosemary Brook -Wellesley	2.00	None	Groundwater	Chlorination, Coagulation, Sedimentation, Filtration	Satisfactory, however direct filtration should be investigated.
Chicopee River Canal -Chicopee	10.0	Color, Turbidity, Iron	Surface	Chlorination, Coagulation, Sedimentation, Filtration, Activated Carbon	Satisfactory, however direct filtration should be investigated.
Cooley Brook & Morton Brook Reservoirs -Chicopee	3.03	Color	Surface	Chlorination, Coagulation, Sedimentation, Filtration	Satisfactory, however, direct filtration should be investigated
Lake Cochituate Wells -Framingham	3.00	Manganese	Groundwater	Chlorination, Manganese Removal	Filtration will probably be required
Buckmaster Pond -Westwood	1.50	Color, Iron, Turbidity, Trichloroethane, Trichloroethyene	Groundwater	Chlorination, Iron Removal, Activated Carbon	Filtration will probably be required.

UNRESOLVED ISSUES/ FUTURE STUDIES

Issues which need to be investigated in future phases of this study include the following:

- Evaluation of the $480 per million gallons limit to determine "practicality" of reactivation;
- Use of existing supplies for industrial demands to replace present and future demands on the MDC system;
- Potential of future contamination of reactivated supplies;
- Required modifications to the MDC user community systems;
- Impacts of supply development on downstream surface waters or ground water levels;
- Estimated safe yield of each source;
- Present water quality and required treatment of the identified sources;
- Institutional options for financing supply development;
- Current water quality data on each source; and
- Development of treatment requirements, methods, and estimated costs.

)CAL SOURCES-
:YMOUTH AQUIFER

Background

During the NEWS studies, the COE sponsored a study of the ground water resources of Massachusetts by the United States Geological Survey (USGS). "The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs..." In the study, the COE concluded that only "aquifers underlying Plymouth County and parts of Cape Cod have the capacity to sustain long term large magnitude withdrawals". In the 1969 Feasibility Report, the COE proposed development of 12 mgd and 28 mgd from the Plymouth aquifer to meet the 1990 needs of north Plymouth County and Bristol County. In later studies of the Millers River Basin and Merrimack River Basin the COE evaluated as alternatives the potential of the Plymouth aquifer to export 210 mgd to the MDC system to meet 1990-2020 demands. (USCOE, 1977)

In view of the above, it appeared possible that the 70 mgd flow augmentation objective of the Northfield Mountain EIR-Phase I study could be met from the Plymouth aquifer and a brief review of the existing hydrogeologic literature and evaluation of the hydrologic parameters cited was performed to evaluate this hypothesis.

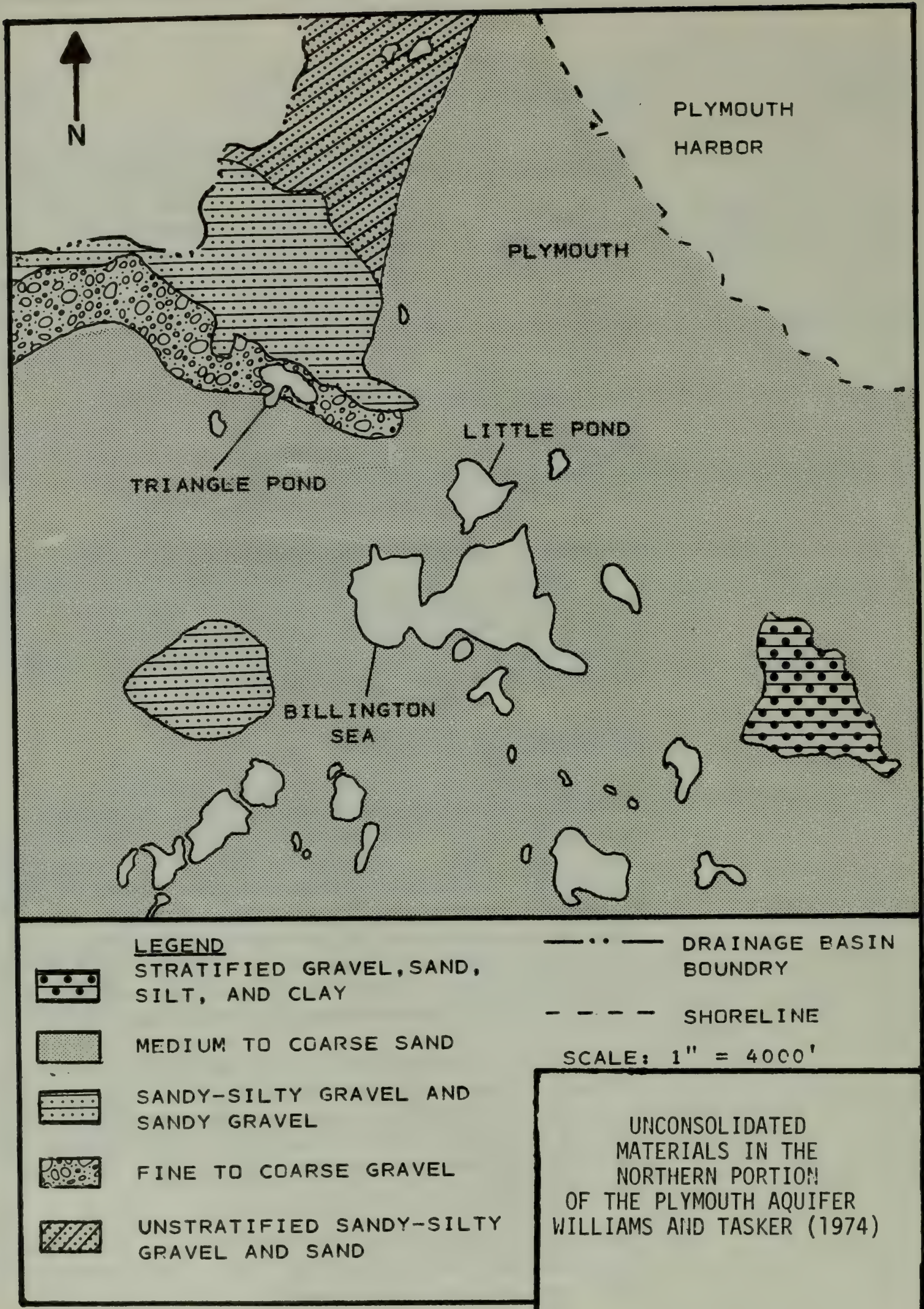
Description of Aquifer

The Plymouth aquifer lies beneath Plymouth and adjacent parts of Wareham, Carver, and Kingston townships. The aquifer materials are primarily sand and gravel deposits (Frimpter, 1973). As shown in Figure 7, the northern portion of Plymouth township contains extensive deposits of these coarse grained materials. Hydrogeologic information for this section of the aquifer was obtained from a hydrologic study of the aquifer conducted by the United States Geological Survey (Williams and Tasker, 1974). A summary of this information is presented in Table 14.

The hydrologic character of this portion of the aquifer indicates that a high development potential is available. High hydraulic conductivities, large saturated thicknesses, and the relatively uniform nature of these materials are ideal conditions for the development of a high yield ground water pumping system.

The principal negative factors affecting the development of this resource are the recharge rate, the amount of available storage, and water quality.

The recharge rate presented in Table 14 primarily represents a temporary storage from surface runoff and influent seepage of streams during peak flow periods. During low flow periods the ground water system maintains stream and pond levels by effluent seepage (Williams and Tasker, 1974).



UNCONSOLIDATED MATERIALS IN THE NORTHERN PORTION OF THE PLYMOUTH AQUIFER WILLIAMS AND TASKER (1974)

FIGURE 7

TABLE 14

SUMMARY OF HYDROGEOLOGIC INFORMATION FOR THE NORTHERN PORTION OF THE PLYMOUTH AQUIFER (WILLIAMS AND TASKER, 1974)

PARAMETER	RANGE OF VALUES
Hydraulic Conductivity	40 to 475 feet per day
Saturated Thickness	50 to 100 feet
Storage Coefficient*	0.2
Transmissivity**	15,000 to 350,000 gallons per day per foot (2,000 to 47,000 ft^2 per day)
Water Table Elevation	20 feet above sea level in the east 120 feet above sea level in the west
Estimated Aquifer Storage***	540 billion gallons
Estimated Recharge ***	120 million gallons per day (43 billion gallons per year)
Critical Chemical parameters:	
Iron	>0.3 milligrams per liter
Manganese	>0.05 milligrams per liter

* from Army Corps of Engineers Report (1969)

** calculated from existing data

*** values are for total area of aquifer

Yield

In the NEWS studies of the Millers River Basin and Merrimack River Basin, the COE indicated that the Plymouth aquifer has an estimated safe yield of 300 mgd. Although sufficient data was unavailable, our analysis of existing hydrological data indicates that a 70 million gallon per day ground water supply system is technically feasible. However, the introduction of a high yield pumping system which removes ground water from the basin will lower ground water and surface water levels. Both Lathrop (1974) and the COE cited the impact that lower ground water levels would have on lakes, rivers and bogs utilized for cranberry production. (USCOE, 1977)

The impact of withdrawal of 70 million gallons per day from the hydrosystem can be summarized in two categories- water balance and water quality.

The current ground water and surface water utilization rate for the Plymouth aquifer region is approximately 24 million gallons per day. The return of waste water to the system is approximately 22 million gallons per day. The net recharge-discharge relationship between ground water and surface water is 125 million gallons per day (Williams and Tasker, 1974). With the addition of a 70 million gallon per day extraction from the basin hydro-system, a net loss of 72 million gallons per day results. This represents a loss of over half of the ground water contribution to the surface water system.

The ground water quality of local wells may be adversely affected by removal of large quantities of ground water. Degradation of ground water may also occur by the addition of iron and manganese from nearby bogs when the cone of influence from the well pumps extends under the bogs. Reduction of ground water levels by pumping may also cause salt water intrusion along the coastal margin of the aquifer (Frimpter, 1973).

The amount of storage available in the aquifer for use during periodic drought years is small. The presence of a high production well field exporting ground water from the basin without any additional recharge would cause a serious depletion of storage in the aquifer, and magnify the impacts on receiving lakes and streams.

Additional studies should be made to determine what quality of water could be developed from the aquifer and exported from the basin which would result in acceptable impacts on existing lakes, rivers and wells.

Water Quality

Water quality data listed in Table 15 was obtained from the Groundwater Management section of the report on the Southeastern New England Study (Frimpter, 1973). These figures give the range of average water quality reported by the Massachusetts Department of Public Health in 1970 for the Plymouth aquifer.

The water quality data in Table 15 indicates that treatment will be required for iron and manganese. This data coincides with the area's history of iron and manganese degradation which has required abandonment of some wells in southeastern Massachusetts.

In the absence of a detailed chemical analysis of the raw water from the aquifer, this water quality summary serves only to establish the need for an iron and manganese treatment plant in the conceptual system design. The bacteriological quality of the raw water from the aquifer is expected to be good. Some degree of disinfection would take place during prechlorination in the treatment process.

Operation

Under this alternative water would be pumped continuously from the Plymouth aquifer, treated for iron and manganese, and then pumped through a conveyance pipeline to Shaft 7D of the MDC's Dorchester tunnel and delivered to user communities in the southern portion of the MDC system via existing MDC facilities.

Facilities

The facilities developed during the conceptual engineering studies to develop the 70 mgd supply objective from the Plymouth aquifer are shown in Figure 8, briefly summarized below and later discussed in more detail.

- Well field - 55 wells each rated @ 1.4 mgd;
- Well collection pipeline system - 82,000 feet of pipeline;
- 5 million gallon equalizing reservoir;
- 70 mgd water treatment plant;
- 5,000 Hp pump plant; and
- 60 inch diameter concrete conveyance pipeline, 175,000 feet in length.

TABLE 15

Plymouth Aquifer
Water Quality Summary

Water Quality Parameter	Range of Concentrations[1]	EPA Secondary Drinking Water Standards[2]	Comments on Quality
Color	0-6 Color Units	15 Color Units	Adequate
Ph	5.7 - 6.4	6.5 - 8.5	Acid - treatment will be required for corrosivity
Hardness	13 - 27 (mg/l)	N/A	Adequate
Iron	.02 - .22 (mg/l)	0.3 (mg/l)	Treatment will be required for iron removal
Manganese	.00 - .09 (mg/l)	.05 (mg/l)	Adequate
Chloride	12 - 16 (mg/l)	250 (mg/l)	Adequate
Sodium	5.7 - 8.4 (mg/l)	Public notification required over 20 (mg/l)	Adequate

1 Frimpter, 1973

2 Federal Register, 1979

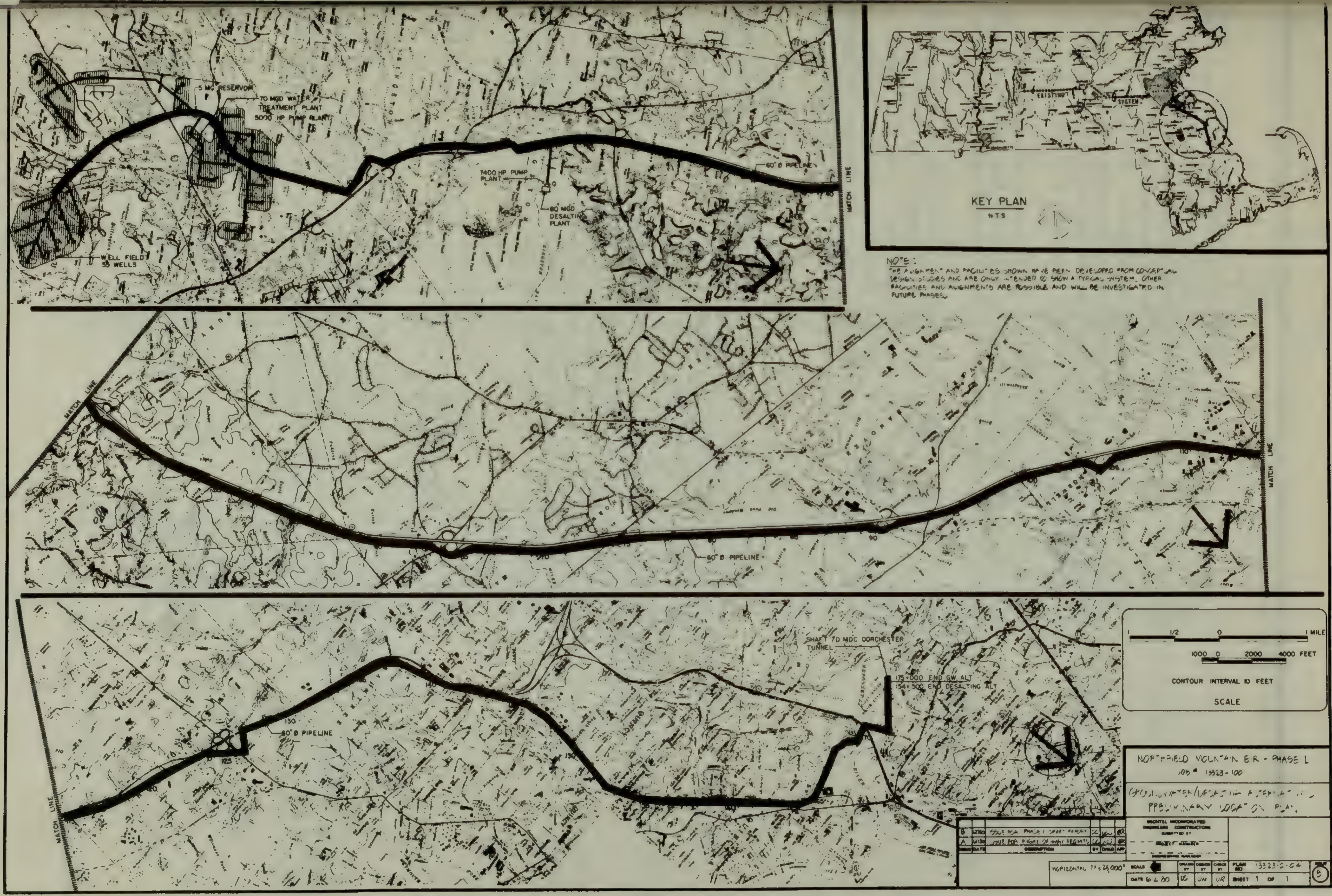


Figure 8

Originals at scale 1" = 25,000' are available for review at MDC or NCAC

Other well field locations, well spacing and well collector systems, pipeline alignments, water treatment facilities, and combinations of pipeline diameter and pumping plant size and terminal connection locations are possible and should be evaluated in subsequent phases. The above combination of facilities provide a reasonable basis for developing an order-of-magnitude estimate of the cost of developing and delivering water via this alternative.

The facilities described above only approximate those developed by the COE because of the substantially different demand objectives between the EIR and COE studies.

Well Field. As shown in Figure 8, two sites were selected for prospective well fields. Site number 1 is located along the northern and southern shores of the Billington Sea. Site number 2 is located along the northern shore of Triangle Pond. The geologic materials present at these sites are medium to coarse sand and sandy silty gravel, and sandy gravel.

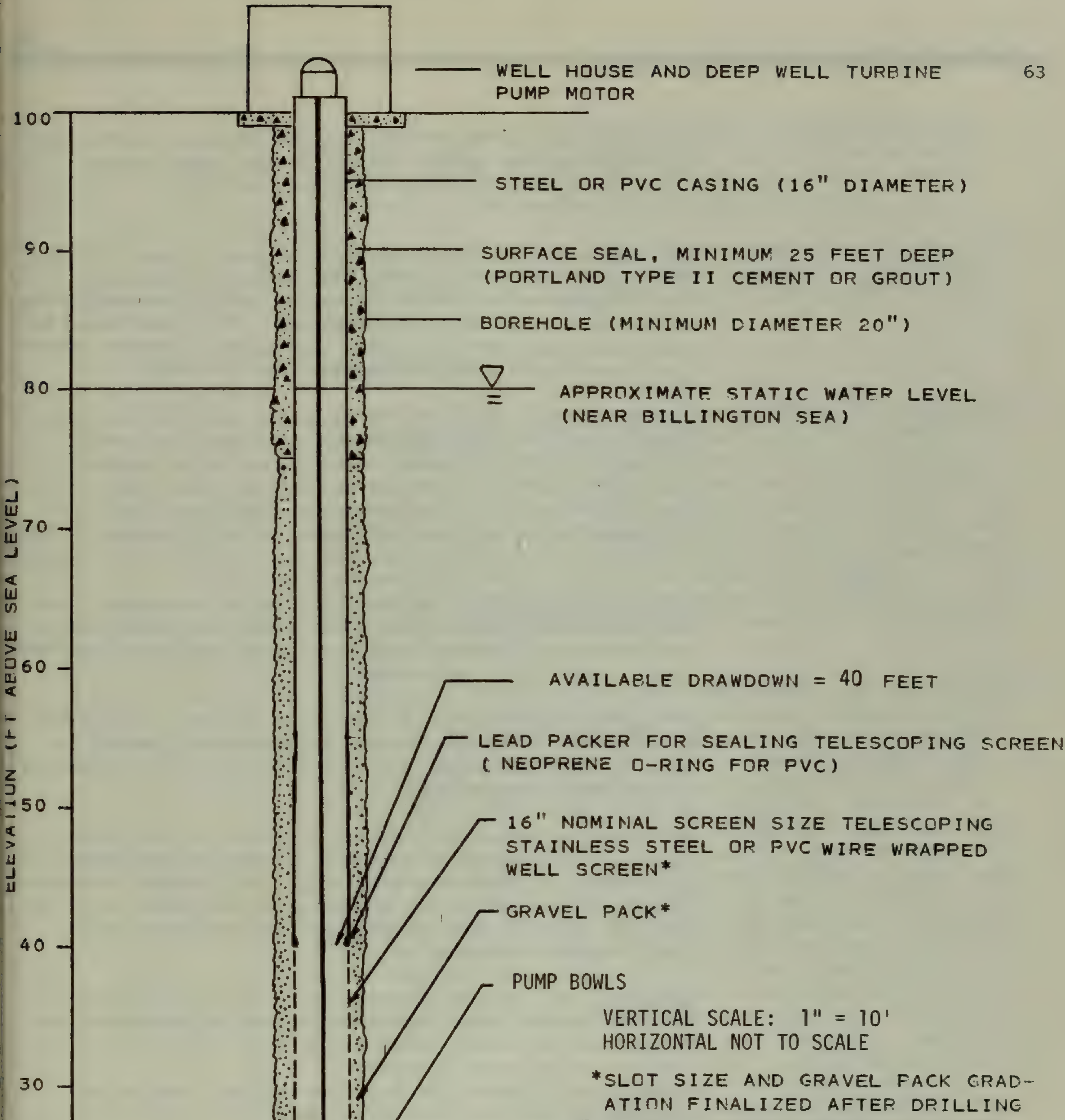
Both sites would be needed to develop the water supply objective in order to reduce local drawdown effects. The well fields would be aligned along the shorelines and as close as possible to the lakes to make efficient use of recharge from the lakes.

A conceptualized schematic of the water production well selected for this study is shown in Figure 9. The well would have steel or PVC casing and stainless steel or PVC well screen, with a gravel pack to maximize well efficiency. The well screen length was selected to obtain a production rate of 1,000 gallons per minute (1.4 million gallons per day).

The spacing of production wells would be a minimum of one thousand feet assuming recharge from Billington Sea or the other contiguous ponds.

Insufficient data was available to make quantitative estimates of yields for wells at these sites. Qualitative evaluation suggests that yields could be as high as 2,000 gallons per minute (3 million gallons per day). The city of Plymouth has two production wells east of the Billington Sea which yield 1.1 and 2.9 million gallons per day (Williams and Tasker, 1974).

Fifty (50) production wells with a yield of 1.4 million gallons per day would be needed to produce 70 mgd. An additional five wells were added to provide an allowance for scheduled maintenance and emergency shutdowns.



PRELIMINARY PRODUCTION WELL DESIGN

Figure 9

Deep well turbine pumps rated at one thousand (1,000) gpm and 60 horsepower motors would lift the ground water to an equalizing reservoir at elevation 200.

In response to current Massachusetts regulations limiting the use of land within a 400 foot radius of domestic water supply wells, about 1350 acres within and contiguous to the well field would be purchased. This land would become open space and be closely controlled to reduce potential contamination of the aquifer near the wells.

Well Collection Pipeline. Groundwater would be conveyed from the wells to the equalizing reservoir via a well collection pipeline system. The layout of the system developed for the well field assumed for this study is shown in Figure 8. Pipeline sizes would vary from 10 to 36 inches depending upon the number of wells served. Over 82,000 feet of pipeline would be required for this layout.

Equalizing Reservoir. A 5 million gallon membrane lined open reservoir would be provided to balance variations in well discharge rates and pressures with the water treatment plant process flow requirements.

Water Treatment Plant. As mentioned earlier, the ground water must be treated for iron and manganese removal in order to meet EPA drinking water standards. Adjustment of pH may also be required.

The unit processes selected for treating the raw water were aeration, chemical addition, flocculation/coagulation, sedimentation, high rate filtration, and sludge thickening. Neutralization of the low pH corrosive raw water prior to aeration would be provided by lime dosing at the well field pumping stations.

Aeration. Aeration of the raw water would take place in tower aerators. Some oxidation of iron and manganese and release of dissolved gasses would be accomplished.

Chemical Addition. Alum for coagulation, lime for pH adjustment, and chlorine for oxidation and disinfection would be added.

High Rate Filtration. Further suspended and colloidal impurities would be removed from the water by passage through a proven medium, usually a bed of sand or other granular material.

Sludge Thickening. Sludge and/or waste water would be generated in the treatment processes described above through sedimentation and by the filter backwash operation and aeration. Waste water or sludge from each operation would

be transferred to thickening tanks and subsequently to a sludge lagoon. Post-chlorination for disinfection would be performed by the MDC via existing facilities prior to delivery to the community distribution systems.

The systems described above and process are among many that would accomplish the intended objective. Additional studies would be performed to select the optimal configuration.

Pumping Plant

A pumping plant would be required to lift the treated water from elevation 190 at the treatment plant to elevation 270 required by the MDC at Shaft 7D and to provide for friction losses in the conveyance pipeline. Five 12,000 gpm pumps and 1,250 Hp pump/motor units were selected for this facility. One unit is an installed standby and would only be used in the event of failure of one of the other four units. The units would be contained in a pumphouse. Power was assumed available at Plymouth and a 13.8 Kv line from the plant to a Plymouth switchyard was included for this alternative.

Pipeline. A 60 inch diameter prestressed concrete pressure pipe would convey treated water from the treatment plant to Shaft 7D. Concrete appeared to have the best combination of properties for the expected trenching conditions, pipe diameter and pressure but other pipeline materials may be competitive and would be evaluated in future studies. The pipe diameter was selected on the basis of judgement of economic tradeoffs between pipe diameter and pumping power. A smaller pipe would require a larger pump plant and higher annual energy costs and vice versa. A study of the economic size should be performed in future studies to obtain the most economical balance between capital and operating costs. The pipeline alignment was selected to minimize disturbance to existing infrastructure and urban communities without excessively deviating from the shortest practical route to Shaft 7D. Trenching conditions were estimated from soil survey maps prepared by the Soil Conservation Service and USGS typographic maps. Detailed alignment surveys and studies should be performed in future studies to obtain the best combination of cost and environmental impacts. The proposed alignment should provide for this phase a reasonable basis for determining an order-of-magnitude cost estimate. A suitable site for a stand pipe was not evident; consequently, an air vessel and air inlet valves would control transient pressures during sudden pump plant shutdowns. This method of transient control is very expensive. Other measures may be more cost-effective and should be evaluated in future studies.

Energy Requirements

Substantial amounts of energy would be required to operate well pumps, the pumps and equipment in the water treatment plant and to pump the water from the treatment plant to Shaft 7D. Electrical requirements are summarized below:

- Well pumps - 20,000,000 kwh/yr
- Water Treatment Plant Equipment - 10,000,000 kwh/yr
- Conveyance Pump Plant - 33,000,000 kwh/yr

Future Studies

Issues which need to be investigated in future phases of this study include the following:

- Evaluate impact of ground water withdrawal on receiving lakes, rivers, wells, and salt water barriers;
- Evaluate possibilities of importing waste water to replace exported groundwater to maintain water balance;
- Alternative well field locations and arrangements including the use of a collection well system;
- Alternative treatment processes, pump plant and pipeline sizes, materials and alignments;
- Alternative delivery points to existing MDC system or present/future Norfolk or north Plymouth County user communities;
- Collection of hydrogeologic data from other existing wells in the aquifer;
- Estimate safe yield of aquifer;
- Collection of additional ground water quality data;
- Assess the potential of future contamination.

DESALTING
(DESALINIZATION)

Background

The COE in their NEWS studies evaluated desalinization currently referred to as desalting, as an alternative for meeting 1990-2020 domestic water demands. (USCOE, 1977) As the desalting processes have been undergoing technological changes since the original COE review, an updating of the present state of the art was performed and is summarized in this section.

Desalting Processes

Fresh water may be produced from sea or brackish water by a number of processes. At present, there are several types of desalting processes which are important commercially. They fall into two categories:

1) Phase Change - This includes distillation and freezing. Freezing is not developed to the point where it can be considered for a large, municipal water supply facility. The workhorse of the desalting industry is multistage flash (MSF) distillation; and

2) Membrane - This includes reverse osmosis and electrodialysis. For seawater desalting, reverse osmosis is just becoming economically viable with the development of suitable membranes to withstand the required pressures.

Of all desalting plants in the world over 1 mgd in size (total capacity estimated at 1240 mgd), more than 80% are of the MSF type; these are predominantly located in the Middle East and North Africa. Between January 1977 and January 1980, the total capacity of MSF plants nearly doubled with the award of several large contracts in Saudi Arabia - one plant will have a reported capacity of 240 mgd. Reverse osmosis (RO) is just beginning to challenge MSF as a contender for seawater desalting. A number of RO installations much smaller than 1 mgd have been built over the past years. One installation with an ultimate capacity of 3 mgd is being built for highly brackish water, located in Russia near the Caspian Sea. The largest seawater RO facility is in Jeddah, Saudi Arabia, with a capacity of 3 mgd.

Distillation Processes. In the multi-stage flash (MSF) process, saline water is heated under pressure to prevent boiling and then flashed through a number of stages at successively lower pressures. In this manner, boiling will not occur directly on a heat transfer surface and fouling/scaling problems are minimized. Water vapors (steam) produced by flashing are condensed and the residual heat is used to partially preheat incoming seawater.

By providing more or less heat transfer surface, the economy of the plant - usually expressed as pounds of product water per pound of steam supplied - may be varied. The process requires removal of large quantities of heat. This is normally accomplished by contact with a flow of cooling water. The MSF plant requires seawater for both evaporation and cooling and produces two reject streams: brine with a water quality of about 70,000 parts per million (ppm) of total desolved salts (TDS) and a much larger seawater stream about 10-15^{o}F warmer than the ambient temperature. Care must be used in design of the intake and outfall facilities so that mixing and recirculation of the brine and cooling water with the intake water does not occur. Water produced from a distillation process will be of very high purity, typically between 5 and 50 ppm TDS. This product must be treated to adjust its acidity and decrease its aggressiveness to metallic piping systems. Other distillation processes, used to a much smaller degree than MSF, include vertical-tube multiple effect evaporation, horizontal tube (spray film) multiple effect evaporation, vapor compression, and submerged tube evaporators.

Membrane Processes. Reverse osmosis (RO) uses a membrane which selectively permits the passage of water but retains (to varying degrees) dissolved material. The normal osmotic flow of water from a less concentrated to a more concentrated solution is reversed by application of pressure to the seawater side of the membrane, and water is forced to flow from the seawater to a fresh water receiver. Since small amounts (depending on the type and characteristics of the particular membrane) of dissolved salts also flow through the membrane, the fresh water produced typically contains about 300 to 500 ppm TDS. The process may be designed to produce water of intermediate purity in a first stage, and then further purified to the desired concentration in a second stage. RO systems require, as an integral part of the facility, pretreatment of the incoming seawater to remove suspended particulate material. Without pretreatment the RO membranes will rapidly foul and require frequent cleaning.

Electrodialysis (ED). ED is used in many brackish water desalting plants (usually somewhat less than 1 mgd in size). This process uses two types of membranes which permit the passage of charge ions and retard the passage of water. Under an electric potential, the positive and negative ions flow through appropriate membranes, alternately arranged so that seawater entering a central passage is depleted of its salt content. The primary power requirement for this process is an electrical field and depends upon the feedwater concentration. Seawater, with an average concentration of 35,000 ppm TDS cannot yet be desalted economically with this process. ED currently is

applied only to waters containing a total desolved salt (TDS) concentration up to about 5000 ppm. Commercial application of ED for seawater conversion must be considered to be sometime in the future.

Other Processes. Crystallization, or the separation of relatively pure ice crystals when water freezes, has been undergoing development for a number of years, but is not yet used commercially. This process appears to have potentially significant cost advantages over both distillation and reverse osmosis for seawater service. It appears several years of development research are required before this process will be commercially competitive.

Yield

The source of seawater is sufficient to supply a 70 mgd distillation (MSF) plant the necessary amounts of water for product water, concentrate water and cooling water.

Water Quality

As mentioned in the preceding section on Distillation Processes, the water produced by MSF would be very pure and would meet all EPA drinking water standards. Treatment to adjust for acidity would be required.

Facilities

A MSF plant was selected for this phase of the EIR study on the basis of lowest estimated cost per 1000 gallons of treated water.

A site selection survey would be required to determine a suitable site. However, for the purposes of this study a site was arbitrarily chosen on Kingston Bay in order to develop some indication of the size and cost of the conveyance facilities.

The actual site could be closer to or further from the MDC system. Sites along the North Shore as well as the South Shore would be considered in future studies.

The facilities for this alternative would consist of the following:

a) 80 mgd distillation (MSF) plant;

b) 7400 Hp pump plant (will vary with actual site); and

c) 60" Ø concrete pipeline - 154,000 ft. (will vary with actual site).

Distillation Plant. The MSF facility would consist of 8 units of 10 mgd capacity each. A plant with 80 mgd installed capacity would be required to produce 70 mgd on a continuous basis as the desalting units need to be shut down periodically for routine maintenance.

Pump Plant. A pump plant would be required to lift the treated water from elevation 20 at the treatment plant to elevation 270 required by the MDC at Shaft 7D and to provide for friction losses in the conveyance pipeline. Five 12,000 gpm pumps and 1,850 Hp pump/motor units were selected for this facility. One unit is an installed standby and would only be used in the event of failure of one of the other four units. The units would be enclosed in a pump house. Power was assumed available at Plymouth and a 13.8 Kv line from the plant to a Plymouth Switchyard was included for this alternative.

Pipeline. A 60 inch diameter prestressed concrete or reinforced concrete pressure pipe was selected to convey treated water from the treatment plant to Shaft 7D of the MDC Dorchester tunnel. The comments pertaining to the pipeline in the Plymouth ground water alternative also apply to this alternative.

Energy Requirements

This alternative would be highly energy intensive. Estimates of energy needs are summarized below:

- Distillation process and plant equipment - 1,600,000 barrels of oil/year. (Approximately equivalent to 2,860,000,000 kwh/yr)

- Conveyance Pump Plant - 48,000,000 kwh/yr.

UNRESOLVED ISSUES/ FUTURE STUDIES

Issues which need to be investigated in future phases of this study for the Desalting Alternative include the following: (if this alternative is to be carried forward)

- The impact of future energy increases on the annual operating expenses;

- Site selection study;

- Surveys to locate potential brackish water sources; and

- Evaluation of a combined power/desalting facility.

COST ESTIMATES

In order to provide a means of comparing alternatives with widely different capital and operating costs, life, and yield, the accepted method annualized costs was adopted. Order-of-magnitude estimates were made of the capital and operating costs of each alternative. These costs were then converted into annualized costs and used to roughly estimate the annual cost per million gallons to develop, treat, and deliver water to the MDC system.

When using the costs developed for this phase of the study, recognition must be given to the preliminary status of the design data, engineering designs and the order-of-magnitude methods used to develop the costs. More refined cost estimates developed in future phases on the basis of new data or refined engineering designs may vary substantially from those developed for this phase particularly if the yield objectives are changed. The order-of-magnitude cost estimates should not be used to precisely rank alternatives or to select a preferred alternative. A summary of the preliminary estimates of capital, operating, and annualized costs is shown in Table 19 at the end of this section.

Annualized Costs

Some alternatives have substantially different components of capital costs. Others have different water supply yields. For rough comparison purposes and for determining a measure of the annual cost of developing and operating the facilities, capital costs were converted to annual costs. For this study, the capital recovery factor was computed by assuming the interest rate would be equal to the cost to the MDC to finance bonds for the project and the life of the facilities would be fifty years, except the desalting plant and wells which were estimated at 20 and 30 years respectively. Fifty year life is a commonly accepted figure for determining annualized costs for the civil portions (concrete structures, tunnels, pipelines) of water resource projects. Shorter lives were assumed for the desalting plant and wells to reflect the corrosive action of the seawater on the desalting equipment and progressive degradation of the well field and wells.

The capitalized costs were then added to operation and maintenance and replacement costs, and divided by the annual supply developed for each alternative. The result is an estimate of the annual costs of servicing the capital cost debt and operating the facilities per million gallons of developed water supply.

Capital Costs

All capital costs are based on July 1, 1980 pricing levels and do not include any provisions for permits, licenses, fees, owner's administration expenses, or escalation. "Ball park" estimates of land acquisition and easement

were provided by the MDC for land requirements developed from the conceptual layouts (MDC, 1980).

Capital costs for the Merrimack River, Millers River, Northfield Mountain, Plymouth Groundwater, and Desalting Alternatives were based on the conceptual engineering designs and were developed from unit prices, cost curves or other order-of-magnitude cost estimating techniques for similar facilities. They include the following allowances:

- Contingency - 20%
- Engineering and Construction Management - 10%
- Interest During Construction -

$$\text{Project Cost} \times \frac{8\% \times \text{Est. Construction Period}}{2}$$

Capital costs of the water treatment processes were developed from the publication entitled "Estimating Water Treatment Plant Costs - Volume II", published by the Environmental Protection Agency (EPA).

As mentioned in the discussion on the alternatives, ozone treatment of the Millers River and Connecticut River waters may be necessary at some future time. Since the requirement and timing of this treatment is uncertain, costs for these alternatives are shown with and without treatment.

Upper Sudbury - Sudbury Reservoir Watershed. The 1979 study (Maguire, 1979) reported a capital cost of $7,500,000 for the proposed water treatment plant and annual operation and maintenance costs of $960,000. The reported capital cost of the 30 mgd capacity plant would be equivalent to $250,000 per mgd. This unit cost of capacity compares reasonably with the unit costs of water treatment plants of similar size and capacity constructed in the New England area in the 1970's as shown in Table 16. The 1979 reported cost increased by a 10 percent inflation factor to adjust the cost to a July 1980 cost basis would be $18,250,000.

Capital costs for this plant are sensitive to several factors: structural condition of existing intake structure at Sudbury Dam which would be utilized for the water treatment plant, the possible EPA regulation requiring granular activated carbon contact in water treatment for communities with 75,000 or more people, and the possibility that pretreatment (coagulation and sedimentation) can be eliminated. If careful inspection of the intake works reveals structural or functional deficiencies, the capital cost could be increased by as much as 20 percent. Similarly, if granular

TABLE 16

WATER TREATMENT PLANT CONSTRUCTION COST DATA
(Excerpted from 1979 CE Maguire Report)

Location	Capacity	Bid Date	Bid Price	March 1979 Price	Price/MGD Capacity
Norwich, Conn.	9.5	5/71	$ 2,507,925	$ 4,429,748	$ 466,289
Andover, Mass.	12	5/71	5,200,000	9,184,760	765,397
Manchester, N.H.	30	11/72	4,800,000*	7,089,655	236,322
Fall River, Mass.	24	6/73	4,500,000	6,389,503	266,229

*Price adjusted to remove costs of Series Type GAC carbon filtration.

activated carbon treatment is mandated, an increase in capital costs of 30 percent would be possible.

As previously mentioned, Sudbury Reservoir is a good to excellent source of raw water. Review of the water quality parameters suggests that it may be possible to eliminate the coagulation and sedimentation processes from the treatment plant. Elimination of these unit processes would result in a 20 to 30 percent decrease in capital cost and a corresponding or slightly greater reduction in operating costs.

For annual operation and maintenance costs, the 1979 study uses a figure of $120 per million gallons, or $960,000 per year. Comparison of this figure with other plants of comparable size indicated that this is a reasonable estimate of annual operation and maintenance costs. When indexed to July 1980 price levels, the estimated annual operation and maintenance expenses would be $1,060,000.

Upper Sudbury - Reservoir and River

In the 1975 study (Maguire, 1975) the capital cost of the Allocation Plan C was given as $35,222,040. Of this, $15,000,000 was for a 125 mgd water filtration plant using a microstraining and ozonation process.

The 1979 report updated the costs for Allocation Plan C to March 1979 price levels and also changed the treatment process from microstraining and ozonation to a "traditional water treatment process". The updated capital costs were estimated to be $74,204,932. Annual operation and maintenance costs were estimated to be $1,963,932. The operation and maintenance (O&M) costs for Allocation Plan C do not appear to have included pump plant energy costs. An estimate of these costs was added to the 1979 estimate. When adjusted and indexed to July 1980, the costs of this alternative were:

- Capital Cost - $83,000,000
- Annual O & M - $ 2,430,000

Local Sources - Abandoned or Reserve Supplies

In the 1980 study (Coffin & Richardson, 1980), reactivation costs for abandoned sources were developed from a cost curve representing actual construction costs of treatment facilities in the New England region and item by item cost estimates for specific unit processes. An unsuccessful attempt was made to evaluate the accuracy of the cost curve by comparing it with "Estimated Water Treatment Costs" published by EPA (USEPA, 1979). Since the curve was used to obtain only a small portion of the treatment costs, its impact is limited. Documentation of the item by item

costs for each abandoned source was not reported in this study. In the absence of the itemized costs, the total cost of the facilities was roughly checked against in-house data on costs of similar treatment facilities and found to be reasonable. Table 17 gives a summary of the costs developed in the 1980 report for the eight (8) abandoned sources reviewed. All cost estimates represent the expected costs of facilities on or about September 1, 1980.

These cost estimates will need to be refined in later phases when the yield of the sources are confirmed and updated water quality information has been used to determine the required treatment processes.

Desalting Plant Costs. The cost estimate for the desalting plant was developed from data contained in a recent report, "Desalting Seawater and Brackish Water: Cost Update, 1979" by Larson & Associates, Ltd., for the Department of Energy, issued by Oak Ridge National Laboratory as Report ORNL/TM-6912, August 1979. The referenced report gives costs for units larger than the 10 mgd units selected in the conceptual designs. However, no units larger than about 9 mgd have been built. Capital costs reported in the above report have been modified slightly for this study to reflect current local conditions and also escalated by 10% to adjust them to a July, 1980 cost basis. Fuel and electricity costs given in the referenced report were adjusted to reflect fuel cost information obtained from Massachusetts Electric Company.

All estimates in the report are for a plant located in the U.S. Costs were also included for site development, civil work associated with the installation of intakes and outfalls, and provision of the necessary electrical switchgear.

Capital costs also include indirect costs and interest during construction, working capital, engineering and contingency. A summary of the capital and operating costs of the MSF plant is shown in Table 18.

Operation and Maintenance (O&M) Costs. Except for the O&M costs previously discussed, operation and maintenance and replacement costs were developed from EPA curves (USEPA, 1980), in-house data on operating costs of similar facilities and as a percentage of initial capital costs. Percentages of initial costs were obtained from a State of California manual which had been developed from COE, United States Bureau of Reclamation, and Federal Power Commission sources.

TABLE 17

Summary of Water Treatment Costs
(Developed from data Contained in Feb. 1980 Coffin & Richardson Study)

Source Name	Treatment Plant Capacity (MGD)	Water Treatment Construction Costs (From Curve)	Total Cost of Treatment Facilities	Total Cost of Treatment Facilities per MGD
Dedham Avenue Supply -Needham	0.43	$ 53,100	$ 75,000	$ 174,413
Newton Water Works -Needham & Newton	8.00	$ 660,500	$ 6,800,000	$ 850,000
Charles River Wells -Waltham	3.00	$ 283,600	$ 3,000,000	$1,000,000
Rosemary Brook -Wellesley	2.00	$ 200,000	$ 2,100,000	$1,050,000
Chicopee River Canal -Chicopee	20.00	$1,891,500	$19,000,000	$ 950,000
Cooley Brook & Morton Brook Reservoir -Chicopee	6.00	$ 515,000	$ 5,400,000	$ 900,000
Lake Cochituate Wells -Framingham	3.00	$ 284,000	$ 3,000,000	$1,000,000
Buckmaster Pond -Westwood	1.50	Curve was not used for this source	$ 870,000	$ 580,000

TABLE 18

Order-of-Magnitude Capital and Annual Cost Estimates
(2nd Quarter, 1980)

80 MGD Desalting Facility (1)

Capital Costs	$450,000,000(2)	
Annual O & M Costs	$Million/yr	$/1000 gal (5)
Operating (3)	36	1.4
Fuel (4)	28	1.1
Total Annual O & M Costs	64	2.4

Notes:

(1) MSF facility consists of 8 units, each 10 MGD capacity. Operating factor of facility assumed 87.5%.

(2) Includes indirect costs and interest during construction.

(3) Includes labor, maintenance, administration, supplies & chemicals.

(4) Fuel at $2.9/million Btu (oil) used to generate steam and electricity needs of MSF units.

(5) Based on a total production of 25,500 million gal/yr.

TABLE 19

SUMMARY OF PRELIMINARY ESTIMATES OF CAPITAL, OPERATING AND ANNUALIZED COSTS (1)

Alternative	Developed Yield - Average Annual NGD	Estimated Capital Cost $ Millions	Estimated Life Years	Annualized Capital Cost $1,000	Estimated Annual O, M & R Expenses $1,000	Total Annual Cost $1,000	Approximate Cost $/MG/Yr.
Northfield Mountain							
o flood skimming-gravity option	70	73 +10**	50	5660 750**	250* 410**	5910* 1160**	230 50** 280+Energy Costs*
o flood skimming-power option	70	101 +10**	50	7780 750**	940* 410**	6840* 1160**	270 50** 320+Energy Costs*
Connecticut River Tributaries							
o Millers River flood skimming	70	60 +11**	50	4600 810**	225 480**	4825 1290**	190 50** 240
Merrimack							
o flood skimming	70	130	50	10040	5950	15990	630
Upper Sudbury							
o reservoir watershed	21.9	8	50	636	1060	1700	210
o river basin watershed	45	83	50	6410	2430	8840	540
Local Sources							
o abandoned or reserve supplies	31	43	40	3430	2800	6230	550
o Plymouth groundwater	70	103	30/50	7970	6580	14550	570
Desalting	70	509	20	50000	64000	114000	4460

* Off peak power rate unavailable for computing cost of energy for pumping to Northfield Mountain Reservoir.

** Water treatment, if required.

(1) The cost estimates included here are intended only to provide relative order-of-magnitude costs for the capital investment and operating costs of each alternative for the developed yield. Refinement of these estimates must be performed in future studies before conclusions can be drawn as to the most economical alternative(s).

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A P P E N D I X

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Chicopee River Canal

Location: In Chicopee, just west of the Montgomery Street bridge.

Community Served: Chicopee

Type of Supply: Surface

Description: Water taken through a canal, about 2,000 feet long on the south side of the Chicopee River.

Last Reported or Estimated Yield: 10.0 mgd based on minimum flow.

Year Developed: 1883

Year Removed from Normal Service: 1893

Reason for Removal from Service: A mild outbreak of typhoid fever was believed to be related to use of this source.

Treatment Prior to Removal from Service: None

Watershed in which Supply is Located: Chicopee River-Conn. River

Present Ownership and Use of Supply Site: Privately owned industrial area. Canal is no longer in existence.

Reported Water Quality Defects: Color, turbidity, and iron.

Feasibility of Reactivation: Potentially feasible to take water from the Chicopee River.

1978 MDC Water Use by Community: 4,480.84 mg or 12.28 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Chicopee River Canal

Major Downstream Users to be Impacted by Reduced Flow: None - treated wastewater would be returned to the watershed.

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: None

Pollution Sources on Watershed: Residential, commercial, and industrial developments.

Water Quality Parameters Requiring Treatment: Turbidity, color, and iron.

Treatment Required: Chlorination, coagulation, sedimentation, filtration and activated carbon.

Estimated Cost of Treatment: $19,000,000 for a 20.00 mgd treatment plant.

Estimated Total Cost of Reactivation: $20,000,000 including $1,000,000 to purchase land and prepare the site for the treatment plant.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Chicopee River Canal. Water supply for Chicopee, Massachusetts. Average chemical analysis of the Chicopee River for the summer of 1978. Samples taken at the Route 116 bridge in Chicopee. Data from the Massachusetts Department of Environmental Quality Engineering. Chemical values in milligrams per liter.

Number of Samples	4
pH	7.4
Total Alkalinity	19
Suspended Solids	5.3
Total Solids	88.5
Color	36
Turbidity	1.3
Chlorides	15
Total Nitrogen	1.47
Ammonia Nitrogen	.04
Nitrate Nitrogen	.25
Total Phosphorus	.11
Oil & Grease	1.4
Copper	.01
Chromium	.00
Iron	.65
Cadmium	.00
Mercury	.0000
Lead	.00
Zinc	.00
Nickel	.00

Chicopee River Canal
Water Supply for Chicopee, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:25000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Cooley Brook and Morton Brook Reservoirs

Location: In Chicopee, approximately 3/4 of a mile above the Chicopee River, just south of Westover AFB.

Community Served: Chicopee

Type of Supply: Surface

Description: Cooley Brook Res. - surface area 30 acres, drainage area 2880 acres, storage capacity 145 mg. Morton Brook Res. - surface area 4 acres, drainage area 224 acres, storage .2mg.

Last Reported or Estimated Yield: 3.03 mgd.

Year Developed: 1883, Cooley rebuilt in 1913.

Year Removed from Normal Service: 1950

Reason for Removal from Service: Inability to meet the needs of the City.

Treatment Prior to Removal from Service: Chlorination beginning in 1926, rapid sand filtration beginning in 1931.

Watershed in which Supply is Located: Chicopee River

Present Ownership and Use of Supply Site: Chicopee Memorial State Park. Swimmming and other recreation. Owned by the Massachusetts Department of Environmental Management.

Reported Water Quality Defects: Color.

Feasibility of Reactivation. Potentially feasible if swimming in reservoir is eliminated.

1978 MDC Water Use by Community: 4,480.84 mg or 12.28 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Cooley Brook and Morton Brook Reservoirs

Major Downstream Users to be Impacted by Reduced Flow: None - treated wastewater would be returned to the watershed.

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: None

Pollution Sources on Watershed: Runoff from Westover Air Force Base and roads.

Water Quality Parameters Requiring Treatment: Color

Treatment Required: Chlorination, coagulation, sedimentation and filtration.

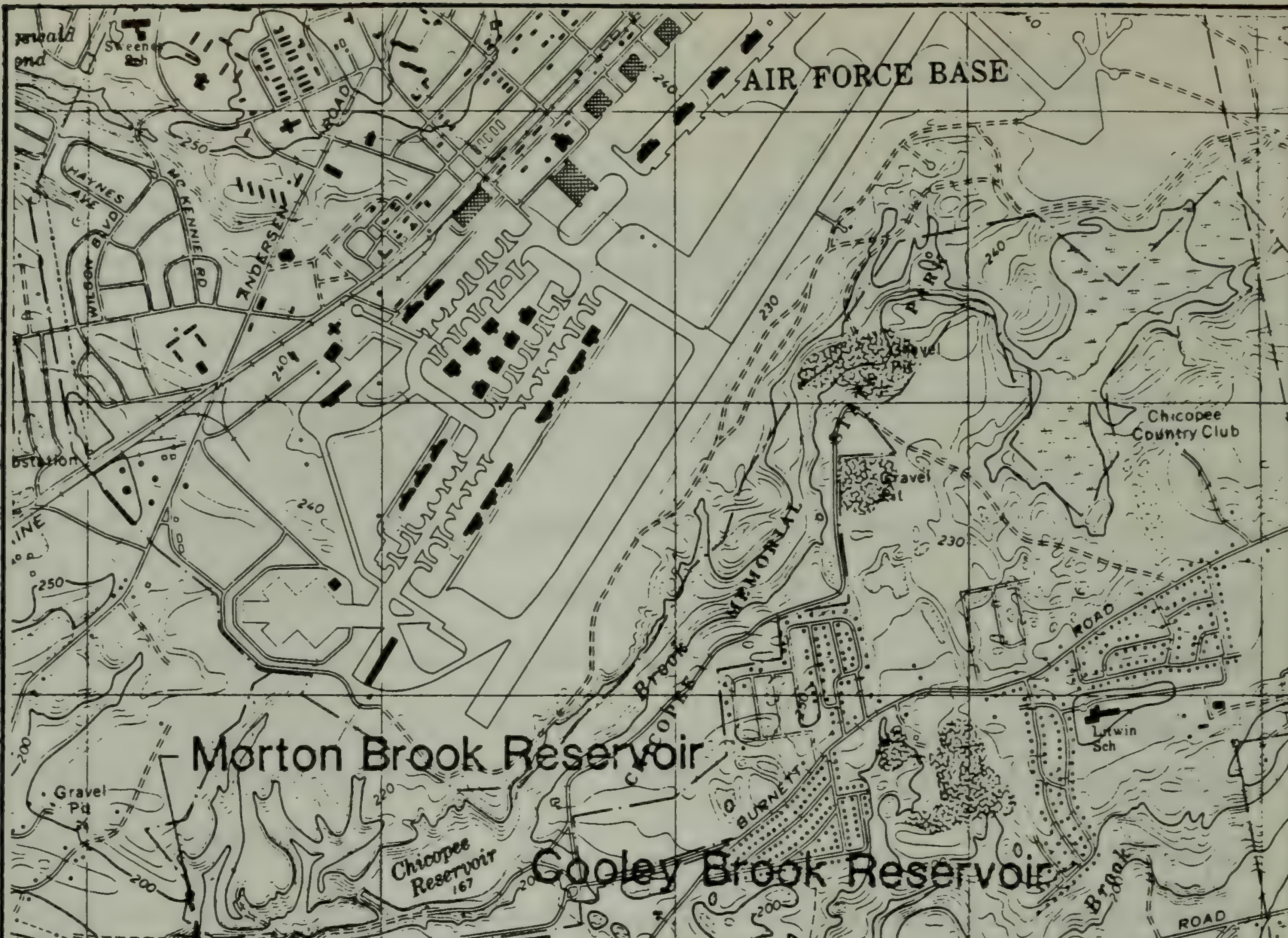
Estimated Cost of Treatment: $5,400,000 for a 6.00 mgd treatment plant.

Estimated Total Cost of Reactivation: $5,700,000 including $300,000 to purchase land and prepare the site for the treatment plant.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Cooley Brook and Morton Brook Reservoirs. Water supply for Chicopee, Massachusetts. Average chemical analysis for 1949. Data from the Massachusetts Department of Environmental Quality Engineering. Chemical values in parts per million.

	Cooley - Raw water	Morton - Raw Water
Number of Samples	3	3
Color	34	7
Free Ammonia	.031	.013
Albuminoid Ammonia	.124	.025
Nitrates	.43	.87
Chlorides	2.7	3.3
Hardness	22	23
Alkalinity	17	12
Iron	.23	.23
pH	6.7	6.6



Cooley Brook and Morton Brook Reservoirs
Water Supply for Chicopee, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:25000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Dedham Avenue Supply

Location: In Needham north of Dedham Avenue between the Charles River and the Penn Central Railroads tracks.

Community Served: Needham

Type of Supply: Surface and Groundwater

Description: Two dug wells, a reservoir to recharge the wells covering 9 acres with a storage capacity of 9 mg, a small spring (Hicks Spring) diverted into the dug wells and 38 tubular wells along the Charles River (Coburn Lot).

Last Reported or Estimated Yield: Dug wells .43 mgd, Total .94 mgd.

Year Developed: From 1890 to 1924.

Year Removed from Normal Service: Tubular about 1935, spring 1964, dug wells in reserve since 1971.

Reason for Removal from Service: Supply no longer needed by community.

Treatment Prior to Removal from Service: Chlorination

Watershed in which Supply is Located: Charles River

Present Ownership and Use of Supply Site: Site of spring is now a park owned by the town of Needham. Site of tubular wells is now occupied by private single family homes. Site of reservoir and dug wells owned by Needham DPW.

Reported Water Quality Defects: Sodium above 20 ppm in 1971 tests.

Feasibility of Reactivation: Potentially feasible - dug wells could be reactivited.

1978 MDC Water Use by Community: 364.37 mg or .99 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Dedham Avenue Supply

Major Downstream Users to be Impacted by Reduced Flow: None

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply:

Public will have to be notified that sodium levels are above 20 mg/l.

Reactivation could have an adverse impact upon the Charles River, particularly during periods of low flow.

Pollution Sources on Watershed: Golf course immediately north of the wells and residential developments on upper part of watershed.

Water Quality Parameters Requiring Treatment: None

Treatment Required: Chlorination

Estimated Cost of Treatment: $75,000 for chlorination only.

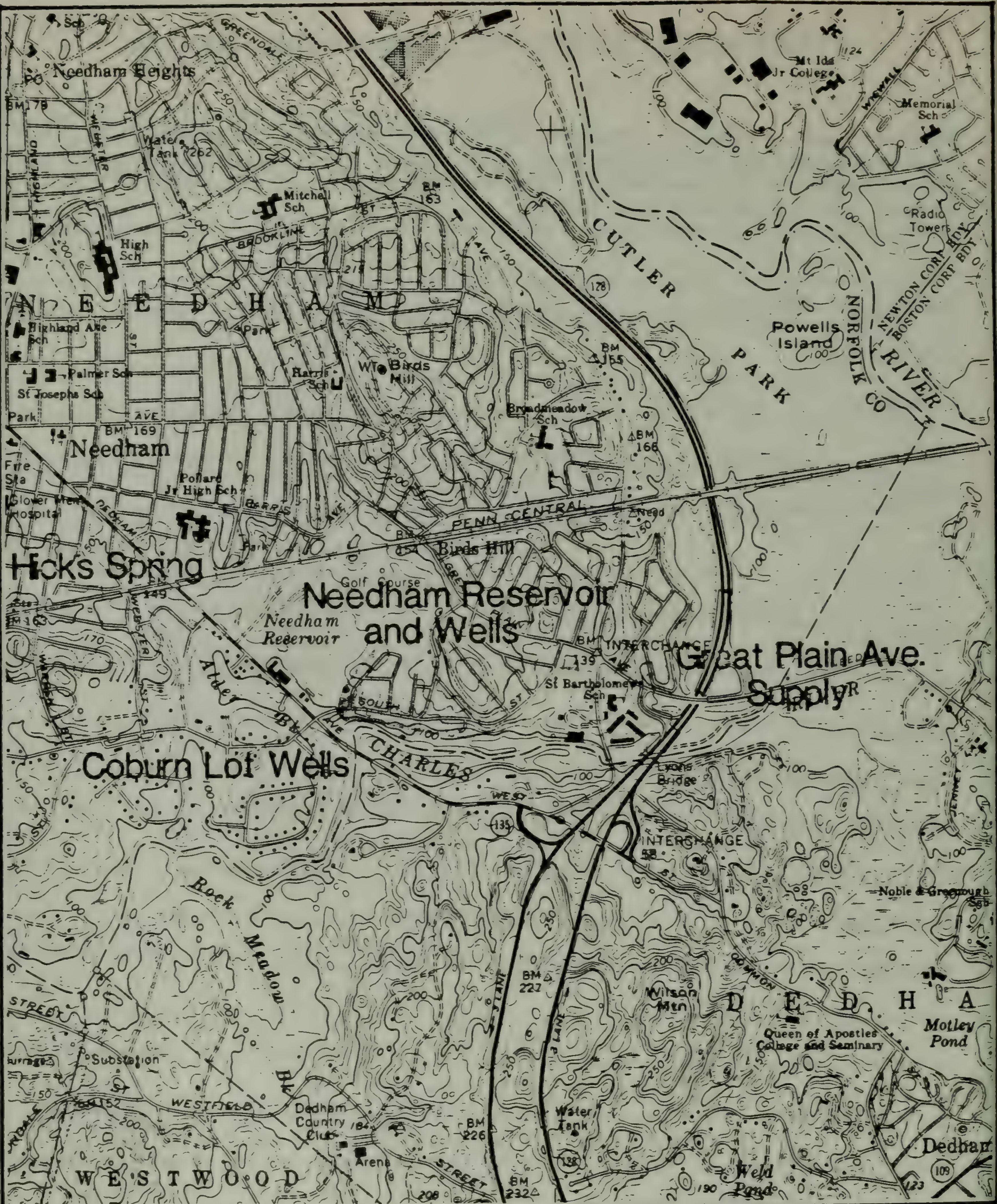
Estimated Total Cost of Reactivation:

$100,000 including $25,000 for a new pump, motor and controls.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Dedham Avenue Supply. Water supply for Needham, Massachusetts. Average chemical analysis for 1971. Data from Massachusetts Department of Environmental Quality Engineering. Chemical values in milligrams per liter.

Number of Samples	3
Turbidity	0
Sediment	0
Color	0
Odor	0
pH	6.3
Alkalinity	16
Hardness	74
Iron	.01
Manganese	.00
Free Ammonia Nitrogen	.02
Nitrite Nitrogen	.001
Nitrate Nitrogen	4.7
Chloride	51
Sodium	22



Dedham Ave. and Great Plain Ave. Supplies
Water Supplies for Needham, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:24000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Newton Water Works Reservation

Location: In Needham and Newton along the Charles River from Needham Street south to the Dedham line.

Community Served: Newton

Type of Supply: Groundwater

Description: 677.5 acre reservation containing an infiltration basin, 4 dug wells and 300 to 400 tubular wells.

Last Reported or Estimated Yield: 8.0 mgd maximum.

Year Developed: Between 1875 and 1938.

Year Removed from Normal Service: 1953

Reason for Removal from Service: Inadequate yield and need to upgrade equipment.

Treatment Prior to Removal from Service: Chlorination, ammoniation.

Watershed in which Supply is Located: Charles River

Present Ownership and Use of Supply Site: Most of site is now owned by the MDC and comprises Cutler Park. The western edge of the reservation is now the site of Route 128 and the northern part is now a privately owned industrial area.

Reported Water Quality Defects: Taste, odor and color.

Feasibility of Reactivation: Potentially feasible to reactivate the section of site within Culter Park.

1978 MDC Water Use by Community: 4,161.64 mg or 11.40 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Newton Water Works Reservation

Major Downstream Users to be Impacted by Reduced Flow: None

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: Reactivation could have an adverse impact upon the Charles River, particularly during periods of low flow. Minimum flows each year are generally less than 8 mgd.

Pollution Sources on Watershed: The watershed is heavily developed with highways, industry, commercial properties and residential neighborhoods.

Water Quality Parameters Requiring Treatment: Color, taste, and odor.

Treatment Required: Chlorination, coagulation, sedimentation, and filtration.

Estimated Cost of Treatment: $6,800,000 for a 8.00 mgd treatment plant.

Estimated Total Cost of Reactivation: $7,800,000 including $1,000,000 for new wells, pumps and mains.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Newton Water Works Reservation. Water supply for Newton, Massachusetts Average chemical analysis for 1953. Data from the Massachusetts Dept. of Environmental Quality Engineering. Chemical values in parts per million.

	Dug Well Number 1	Dug Well Number 2	Dug Well Number 3	Dug Well Number 4
Number of Samples	3	3	4	2
Color	3	3	3	2
Nitrates	.50	.25	.15	—
Chlorides	11.0	13.1	10.9	11.0
Hardness	52	49	44	52
Alkalinity	33	33	31	37
Iron	.04	.03	.02	.02
pH	6.4	6.4	6.3	6.3

Newton Water Works Reservation
Water Supply for Newton, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:25000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Buckmaster Pond

Location: In Westwood, southeast of Route 109, north of Pond Street.

Community Served: Norwood

Type of Supply: Groundwater

Description: Well in reservoir with a surface area of 29.5 acres, a drainage area of 250 acres and a storage capacity of 123 mg.

Last Reported or Estimated Yield: 1.50 mgd.

Year Developed: 1885

Year Removed from Normal Service: Approximately 1957, now a reserve supply.

Reason for Removal from Service: Norwood joined the MDC.

Treatment Prior to Removal from Service: Chlorination and slow sand filtration.

Watershed in which Supply is Located: Neponset River

Present Ownership and Use of Supply Site: Owned by Conservation Commission of Westwood, used as a park, water rights owned by Norwood.

Reported Water Quality Defects: Color, turbidity, iron, sodium trichloroethyline and trichloroethane.

Feasibility of Reactivation: Potentially feasible.

1978 MDC Water Use by Community: 1,498.67 mg or 4.11 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Buckmaster Pond

Major Downstream Users to be Impacted by Reduced Flow: The Dedham Water Company has wells downstream along the Neponset River.

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: Public will have to be notified that sodium levels are above 20 mg/l Reactivation could have an adverse impact upon the Neponset River during periods of low flow.

Pollution Sources on Watershed: Residential developments surrounding pond.

Water Quality Parameters Requiring Treatment: Turbidity, color, iron trichloroethyline and trichloroethane.

Treatment Required: Chlorination, iron removal and activated carbon.

Estimated Cost of Treatment: $870,000 for a 1.50 mgd plant. Estimate by Fay, Spofford & Thorndike, Inc., Boston, Massachusetts.

Estimated Total Cost of Reactivation: $1,000,000 including $130,000 for modification of well and new pumping equipment. Estimate by Fay, Spofford, & Thorndike, Inc., Boston, Massachusetts.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Buckmaster Pond. Water supply for Norwood, Massachusetts. Chemical analysis of February 8, 1975. Data from the Massachusetts Department of Environmental Quality Engineering. Chemical values in milligrams per liter

Turbidity	11
Sediment	0
Color	40
Odor	0
pH	7.3
Alkalinity (Total $CaCO_3$)	54
Hardness ($CaCO_3$)	80
Calcium (Ca)	27
Magnesium (Mg)	3.2
Sodium (Na)	60
Potassium (K)	2.5
Iron (Fe)	1.5
Manganese (Mn)	.13
Silica (SiO_2)	7.3
Sulfate (SO_4)	22
Chloride (Cl)	76
Specific Conductivity (microhmos/cm)	360
Nitrogen as Ammonia	.02
Nitrogen as Nitrate	0.5
Nitrogen as Nitrate	.017
Copper (Cu)	.00

Buckmaster Pond
Water Supply for Norwood, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:24000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Charles River Wells

Location: In Waltham, along the Charles River south of Mt. Feake Cemetary and east of South Street near the Weston line.

Community Served: Waltham

Type of Supply: Groundwater

Description: Dug well (1891) 30 feet deep by 41 feet in diameter; Dug well (1907) 35 feet deep by 30 feet in diameter; Filter basin 1/4 acre x 8 feet, 4 inches deep.

Last Reported or Estimated Yield: 2.5 - 3.0 mgd.

Year Developed: Filter Basin 1873, 1891 - dug well, 1907 - dug well.

Year Removed from Normal Service: 1949

Reason for Removal from Service: Poor water quality.

Treatment Prior to Removal from Service: None

Watershed in which Supply is Located: Charles River

Present Ownership and Use of Supply Site: Not used. 1891 dug well has been filled in with building debris but could be cleaned out. Owned by the City of Waltham.

Reported Water Quality Defects: Iron, manganese and color in 1891 well.

Feasibility of Reactivation: Potentially feasible to reactivate 1891 well. 1907 well is within 200 feet of a large apartment complex.

1978 MDC Water Use by Community: 4,221.73 mg or 11.57 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Charles River Wells

Major Downstream Users to be Impacted by Reduced Flow: None

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: Reactivation could have an adverse impact upon the Charles River particularly during periods of low flow.

Pollution Sources on Watershed: The watershed is heavily developed with highways, industry, commercial properties and residential neighborhoods.

Water Quality Parameters Requiring Treatment: Color, iron and manganese.

Treatment Required: Chlorination and iron removal.

Estimated Cost of Treatment: $3,000,000 for a 3.00 mgd treatment plant.

Estimated Total Cost of Reactivation: $3,300,000 including $300,000 for a new well, pump, pumphouse and mains.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Charles River Wells. Water supply for Waltham, Massachusetts. Average chemical analysis for 1949. Data from the Massachusetts Department of Public Health Annual Report for the Years 1942 through 1949. Chemical values in parts per million.

	1891 Well	1907 Well
Number of Samples	2	2
Color	18	3
Nitrates	.14	.50
Nitrites	.003	.000
Chlorides	9.0	7.9
Hardness	52	41
Alkalinity	65	23
Manganese	.75	.00
Iron	3.8	.03
pH	6.5	6.2

Charles River Wells
Water Supply for Waltham, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:25000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Rosemary Brook Supply

Location: In Wellesley, along Rt. 9 west of Cedar Street.

Community Served: Wellesley

Type of Supply: Groundwater

Description: Filter gallery 63 feet long by 12 feet by 18 feet. Fifty, 2½ inch tubular wells, 30 to 65 feet deep (removed in 1966, but holes not filled). Two gravel packed wells.

Last Reported or Estimated Yield: 2.00 mgd.

Year Developed: 1884

Year Removed from Normal Service: Reserve since 1968.

Reason for Removal from Service: Poor water quality. Department of Public Health ordered status changed to emergency reserve.

Treatment Prior to Removal from Service: Chlorination, corrosion control.

Watershed in which Supply is Located: Rosemary Brook - Charles River

Present Ownership and Use of Supply Site: Owned by Town of Wellesley used as a reserve water supply.

Reported Water Quality Defects: High sodium level and pollution hazar

Feasibility of Reactivation: Potentially feasible.

1978 MDC Water Use by Community: 0 mg.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Rosemary Brook Supply

Major Downstream Users to be Impacted by Reduced Flow: None

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: Public will have to be notified that sodium levels are above 20 mg/l. Reactivation could have an adverse impact upon the Charles River particularly during periods of low flow.

Pollution Sources on Watershed: Sanitary sewer within 400 feet of gravel packed wells. Tubular wells removed in 1966 but holes not filled. Runoff from roads and residential areas.

Water Quality Parameters Requiring Treatment: None

Treatment Required: Chlorination, coagulation, sedimentation and filtration.

Estimated Cost of Treatment: $2,100,000 for a 2.00 mgd treatment plant.

Estimated Total Cost of Reactivation: $2,250,000 including $150,000 for updating of piping.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Rosemary Brook Supply. Water supply for Wellesley, Massachusetts. Chemical analysis of May 7, 1979. Data from the Massachusetts Department of Environmental Quality Engineering. Chemical values in milligrams per liter.

Turbidity	0.5
Sediment	0
Color	0
Odor	0
pH	7.2
Alkalinity (Total $CaCO_3$)	47
Hardness ($CaCO_3$)	82
Calcium (Ca)	24
Magnesium (Mg)	53
Sodium (Na)	25
Potassium (K)	1.4
Iron (Fe)	.19
Manganese (Mn)	.03
Silica (SiO_2)	13
Sulfate (SO_4)	23
Chloride (Cl)	43
Specific Conductivity (micromhos/cm)	290
Nitrogen-Ammonia	.06
Nitrogen-Nitrate	1.6
Nitrogen-Nitrite	.000
Copper (Cu)	.49

Rosemary Brook Supply Water Supply for Wellesley, Mass. Coffin & Richardson, Inc. Consulting Engineers Boston, Mass. Scale 1:25000	**ABANDONED OR RESERVE WATER SUPPLIES** Department of the Army New England Division, Corps of Engineers Waltham, Mass. November 1979

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Lake Cochituate Wells

Location: In Framingham, north of Rt. 126, just west of the Wayland town line.

Community Served: Framingham

Type of Supply: Groundwater

Description: Three, 8 inch diameter gravel packed wells, 69 to 78 feet deep.

Last Reported or Estimated Yield: 3.00 mgd.

Year Developed: 1939

Year Removed from Normal Service: After 1966 used only during the summer months.

Reason for Removal from Service: Poor water quality.

Treatment Prior to Removal from Service: Chlorination

Watershed in which Supply is Located: Sudbury River

Present Ownership and Use of Supply Site: Owned by the Town of Framingham and used as a reserve water supply.

Reported Water Quality Defects: Manganese

Feasibility of Reactivation: Potentially feasible.

1978 MDC Water Use by Community: 3,080.40 mg or 8.44 mgd.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Name of Supply: Lake Cochituate Wells

Major Downstream Users to be Impacted by Reduced Flow: Billerica uses the Concord River. Andover, Lawrence and Methuen use the Merrimack River. Sudbury, Wayland and Concord have wells along the Sudbury River.

Known Water Rights Affecting or Precluding Use of Supply: None

Major Environmental Impacts Associated with Reactivation of Supply: Reactivation could reduce the flow of the Sudbury and Concord Rivers.

Pollution Sources on Watershed: Runoff from roads and residential areas on watershed.

Water Quality Parameters Requiring Treatment: Manganese

Treatment Required: Chlorination and manganese removal.

Estimated Cost of Treatment: $3,000,000 for a 3.00 mgd treatment plant.

Estimated Total Cost of Reactivation: $3,100,000 including $100,000 for new pumps and controls.

ABANDONED OR RESERVE WATER SUPPLIES FACT SHEET

Lake Cochituate Wells. Water supply for Framingham, Massachusetts. Average chemical analysis for 1968. Data from Massachusetts Dept. of Environmental Quality Engineering. Chemical values in milligrams per liter.

	Well No. 1	Well No. 2	Well No. 3
Number of Samples	3	3	2
Color	5	7	3
pH	6.8	6.9	6.8
Alkalinity	53	50	45
Hardness	101	95	87
Iron	.13	.28	.02
Manganese	.52	.11	.03
Nitrate-Nitrogen	0.1	0.1	0.5
Chlorides	20	17	37

Lake Cochituate Wells
Water Supply for Framingham, Mass.

Coffin & Richardson, Inc.
Consulting Engineers
Boston, Mass.
Scale 1:24000

ABANDONED OR RESERVE
WATER SUPPLIES

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.
November 1979

Northfield EIR July 16, 1980

Response to NCAC Comments on Engineering Memorandum

The following numbers correspond to the numbered items in the NCAC July 14, 1980 memorandum (copy attached).

1. Incorporated comment into final draft. (Incorp. F.D.)

2. No - if useful, it could be done in next phase; See abbreviations; Not known; To be provided by WFEM, if any.

3. WFEM to comment - no BI effort.

4. Definition already covers this fact; Incorp. F.D.

5. Shaded areas are reservoir water surfaces.

6. Maguire study was not evaluated in sufficient detail in this phase to respond to question. Review of safe yield and yields during drought and wet years should be studied in future phases.

7. 1975 For "Interim Primary" and 1979 For "Secondary" Drinking Water Standards.

8. Unknown at this time.

9. These were the large drawings attached to the report. They will be reduced and incorporated into final draft.

10. The requirements and responses will be determined in future phases.

11. Incorp. F.D.

12. There is a line missing. Incorp. F.D.; No, will be reviewed in future phases; Comparison of feeder stream water quality data to Drinking Water Standards.

13. DEQE, 1978.

14. This is suggested method of operation developed for conceptual study and cost estimate. Actual operation and parameters need to be studied in more detail.

15. Overburden means soil.

16. Ashenden, 1973.

17. Table is in error. Chloride stds. and 250 not 15 cu, corrected in final draft.

18. Same response as #14 above.

19. Same response as #14 above.

20. Reference is made to the construction requirements for the Bears Den Fault in the text and was meant to include the other zones. These zones only constitute a very small portion of the total length of tunnel.

21. Methodology will be developed in future phases. Would include future treatment of current point source pollution and impact on river water quality.

22. Standard Cubic Feet.

23. Error in text. Changed "regained" to "required".

24. Incorp. F.D.

25. Incorp. F.D.

26. Incorp. F.D.

27. Incorp. F.D.

28. Incorp. F.D.

29. WFEM should respond.

MEMORANDUM

RECEIVED

JUL 15 1980

WALLACE FLOYD
ELLENZWEIG MOORE

RECEIVED
JUL 15 1980

TO: Patricia B. Corcoran, MDC, and Adel Foz, [illegible]
FROM: Marjorie Holland Sackett, [illegible]
DATE: July 14, 1980
SUBJECT: [illegible] comments on Draft Technical Memo on "Conceptual engineering studies and order-of-magnitude cost estimates of alternative water supply sources for augmenting MDC supplies."

1. In the future it would be most helpful if all pages could be numbered.

2. Table 1, Energy Requirements. Will barrels of oil (gas, etc.) be calculated for each alternative? What does "MCF (gas)" stand for? How and when will information designated as "[illegible] cost of off peak power not available" be available? Where are the costs and energy requirements for water conservation, watershed management or NO ACTION alternatives?

3. Introduction, paragraph 3. In which memos are "No Action, Conservation and Quabbin Watershed Management" discussed, and how will information on these alternatives be integrated with this memo?

4. Introduction, last paragraph. In the definition of "flood skimming" it should be noted that floods may occur during any month of the year. Where is the "impact on the river flow illustrated?"

5. Figure 1. Does the shaded area indicate MDC - owned land?

6. Upper Sudbury Watershed Plan. In the statement "this facility would process 21.9 mgd during an average runoff year," what is the range here (i.e. 15-25 mgd in a low or high year, respectively?)

7. Table 2. Upper Sudbury River Water Quality Data. What is the date for "EPA Regulations Drinking Water?"

8. Sudbury unresolved issues/future studies. Who will determine "what controls will be imposed on reservoir levels and releases?"

9. Where are Figures 3, 5, 6, or 8?

10. Merrimack River, intake structure. How would the "structure be sized and located to minimize disturbance to game fish?"

11. Merrimack River, carbon content. What is the reference for the Hayden, Harding and Buchanan report?

12. Connecticut River Tributaries, water quality. Does "Massachusetts Department of Environmental Protection Agency (EPA)" actually refer to two agencies, Mass. DEQE and U.S. EPA? Has consideration been given to work undertaken along the Miller's River by Dr. Edward Klekowski of the Botany Department at the University of Mass. in Amherst? What is the reference for the statement, "the quality of the existing feeder streams is considerably lower than the water quality at the shaft 12 intake to the Quabbin - Wachusett Tunnel?"

13. Table 6, Miller's River Water Quality. Were the "grab samples" taken by EPA or DEQE or both?

14. Connecticut River Tributaries, operation. For what parameters and for how long would "water quality of the river be monitored on a daily basis during the flood skimming period?" Who would do the monitoring?

15. Connecticut River Tributaries, weir and intake. What is meant by "the left abutment would probably be in overburden?"

16. Connecticut River Tributaries, tunnel. What is the Reference for the [illegible] fault?

17. Table 8, Connecticut River and Northfield Reservoir water quality. Chloride data for Northfield Reservoir are at or above EPA Drinking water regulations; this fact should be noted on the previous page under the discussion of "water quality"

18. Northfield Mountain, operation. For what parameters and for how long would water quality "be monitored on a daily basis during the flood skimming period?" Who would do the monitoring?

19. Northfield Mountain, water quality monitoring station. Who would determine the "certain standard of water quality required before any water would be released into Quabbin Reservoir."

20. Northfield Mountain, tunnel and energy dissipating structure---- gravity option. Some discussion should be included here about the three potent fault zones indicated on the map for the proposed northfield alternative. The statement that "the tunnel would probably be constructed in a structurally sound rock" gives no indication that potential fault zones may have been identified in earlier studies.

21. Northfield Mountain, unresolved issues/future studies. How would "projections of future water quality in the Connecticut River at Northfield" be done?

22. Local sources: abandoned/reserve supplies, energy requirements. What does "SCF/yr" stand for?

23. Plymouth Aquifer, water quality, second paragraph. What is meant by "this data coincides with the area's history of iron and maganese degradation which has required abandonment of some wells in southeastern Massachusetts?

24. Plymouth Aquifer, Well Field. The word "projected" should be added to the sentence "Fifty (50) production wells with a yield of 1.4 million gallons per day would be needed to produce the projected required 70 mgd." The requirements of an additional 70 mgd is one of the questions under investigation in the EIR.

25. Cost estimates, annualized costs. Some explanation should be given as to why "the life of the facilities was assumed to be fifty years, except the desalting plant and wells which were estimated at 20 and 30 years respectively."

26. Cost estimates, local sources--------abandoned or reserve supplies. The 1980 study was done by Coffin and Richardson, rather that by Maguire.

27. A bibliography of all references used in the memo should be provided.

28. No scale is given on the map for the Merrimack River alternative.

29. When cost estimates are prepared for the Water Conservation Alternative, consideration should be given to a pamphlet entitled "Water Research in Action," published by the Office of Water Resources and Technology. The document is available from the Oklahoma Water Resources Research Institute, Okla State University, Stillwater, Oklahoma 74074.

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TECHNICAL MEMORANDUM

POWER ANALYSIS

Northfield Environmental Impact Study-Phase I:
Basic Services

Prepared by

Bechtel Incorporated

June 26, 1980

13323-100

POWER ANALYSIS

Summary

This report addresses the impacts of power on the alternatives for the Northfield Water Supply Project Environmental Impact Report. Power costs and availability will affect Connecticut River flood skimming, Millers River flood skimming, Merrimack River flood skimming, ground water and surface water sources and the desalinization alternative. Existing information is utilized where possible and studies proposed or in progress are referenced where applicable.

Northeast Utilities Company (NU) has confirmed that power is available for pumping operations now and in the foreseeable future. NU has not yet furnished projected costs for off-peak pumping power and the rates at which generated power is sold. A final feasibility analysis on the powerhouse in the Northfield to Quabbin diversion tunnel cannot be made at this time but must be done at a later date.

Operating costs determined for pumping operations have been developed under this power analysis portion of the study and the numbers developed have been used in the engineering portions of this study for determining projected operation and maintenance costs. This data will be used for evaluating and weighing costs for the various alternatives.

Other hydropower developments along the rivers in this study have been identified and later studies will evaluate impacts of skimming schemes on these developments.

INTRODUCTION

For any flood skimming scheme, considering the trend in energy availability and cost, it is important to consider any potential for saving energy or recovering energy from each flood skimming scheme. Any discussion must take into account pricing and availability of power. The cost of facilities for recovering power must be compared with the return in revenue from the generation of power.

Some of the miscellaneous aspects of power usage and generation are itemized below.

- In a pump storage operation the difference between base and peak load energy costs must be applied towards the cost of power generation facilities.
- If pumping is required, it will be economical to pump during the more economical base load periods. This applies whether or not power energy can be recovered. If power is purchased from a local utility company at a commercial rate, a base load advantage may not be available.
- Most utility companies generate with a mix of thermal generated power and hydro generated

power. In areas where nuclear generated energy is available, base load power comes primarily from this source.

- Power demand does not affect the base load unit cost. Power demand does affect the unit cost for peaking power since generation facilities are sized on peaking power capacity.

- During nuclear refueling periods, it is advantageous to perform routine maintenance on pumping facilities. Ideally nuclear refueling will occur during periods when pumping is at a minimum and when power demand is below peak levels.

- The estimated constructed life of a nuclear power station is 50 years. At the end of this period the station must be overhauled or reconstructed. Long range planning by utilities has considered these problems and phasing for new stations is in the planning programs.

This report will discuss the availability and cost of power for pumping and expected power returns. Operating costs for all alternatives will be summarized. Power usage comparisons are indicated in Table 1.

Flood skimming for three alternatives will be considered:

- Connecticut River (Northfield)

- Connecticut River Tributaries (Millers River)

- Merrimack River

The Tullys River option for augmenting water to Quabbin Reservoir is not being proposed as a viable alternative and therefore will not be considered in the power analysis study.

<u>Questions That Need to be Answered</u>

The following questions will be evaluated for the three river diversion alternatives:

1. If water is taken by flood skimming, can power be generated?

2. Would there be any return on capital investment?

3. Where would the powerhouse be?

4. Can an existing mill or factory facility with existing power generation equipment be utilized?

ALTERNATE SUPPLY SOURCES POWER COMPARISON

TABLE 1 *

Alternate Title	Off-Peak Pumping Power Cost ($/KWH)	Normal** Pumping Power Cost ($/KWH)	Peak Power Revenue Return ($/KWH)	Power Usage (KWH/Yr) x 10^6	Generated Power Return (KWH/Yr) x 10^6	Water Quantity Availability (MG/Yr)	Water Treatment Power (KWH/Yr) x 10^6
A. Connecticut River Northfield Mountain	***	0.052	***	81.0	27.0	25,550	-
B. Millers River	NA	NA	NA	NA	NA	25,550	5.0
C. Tullys River	NA	NA	NA	NA	NA	NA	NA
D. Merrimack River	NA	0.052	NA	44.0	NA	25,550	30.8
E. Ground Water							
1) Dedham Ave., Needham	NA	0.052	NA	0.13	NA	157	-
2) Newton Water Works, Needham	NA	0.052	NA	2.3	NA	2,920	-
3) Charles River Wells, Waltham	NA	0.052	NA	0.9	NA	1,095	-
4) Rosemary Brook, Wellesley	NA	0.052	NA	0.6	NA	730	-
5) Lake Cochituate Wells, Framingham	NA	0.052	NA	0.9	NA	1,095	-
6) Buckmaster Pond, Westwood	NA	0.052	NA	0.5	NA	548	-
F. Surface Water							
1) Chicopee River Canal, Chicopee	NA	0.052	NA	1.8	NA	3,650	-
2) Cooley Brook and Morton Brook Reservoir, Chicopee	NA	0.052	NA	0.5	NA	1,106	-
G. Plymouth Aquifer	NA	0.052	NA	53.0	NA	25,550	10.0
H. Desalinization	NA	NA	NA	48.0	NA	25,550	2860.0
I. Sudbury River	NA	0.052	NA	4.0	NA	7,030	5.0

*Water quantity estimates are based on information available from reports referenced in the Engineering portion of this study. Power usage estimates were based on water quantity estimates and unit energy costs shown calculated in Appendix No. 1 to this report.

**See Appendix No. 1.

***To be furnished at a later date by NU.

5. Can an existing mill or factory with space but n present generation equipment be utilized?

6. Where can power be sold?

7. What kind of licensing problems will there be?

8. Will water have to be pumped from river into conduits?

9. Is there off-peak power available for pumping?

10. Is there any pumping power available?

11. What effect does skimming have on any other generating facilities, existing or planned, along the river?

12. How would the project affect Massachusetts Municipal Wholesale Electric Company (MMWEC) programs?

13. Are there power requirements for water treatment

The item numbers under the following Alternatives correspond to the numbers of the above questions.

ALTERNATIVES

Connecticut River

Connecticut River water would be transferred via the North field Mountain Reservoir (NMR) to Quabbin Reservoir (QR). It is anticipated that flood skimming would be only durinc the spring freshet season.

At the present time the 4-feet height addition to NMR Dam (1150 acre-feet) is being used by Northeast Utilities Company (NU). Most of a week's supply of water for generatic is pumped into NMR during Sunday night. Generation begins about 8 a.m. and continues during the day as demanded by the system. System demands are coordinated by Northeast Power Exchange (NEPEX). Some water is pumped back into NMR during weekday evenings but NMR is not filled to capacity until the following Sunday night. A typical operatin cycle is indicated in Figure 1. The fluctuation and staging is not constant or predictable.

If a tunnel to QR was constructed with a power generating facility, then the cost of the power station would be amo tized by the difference between the cost of pumping power into NMR and the revenue returned by the power generated in the NMR to QR power station.

- The powerhouse could be operated from the NMR powerhouse and all generated power could be returned to the Northeast Utilities system. In this situation the utility company may be able

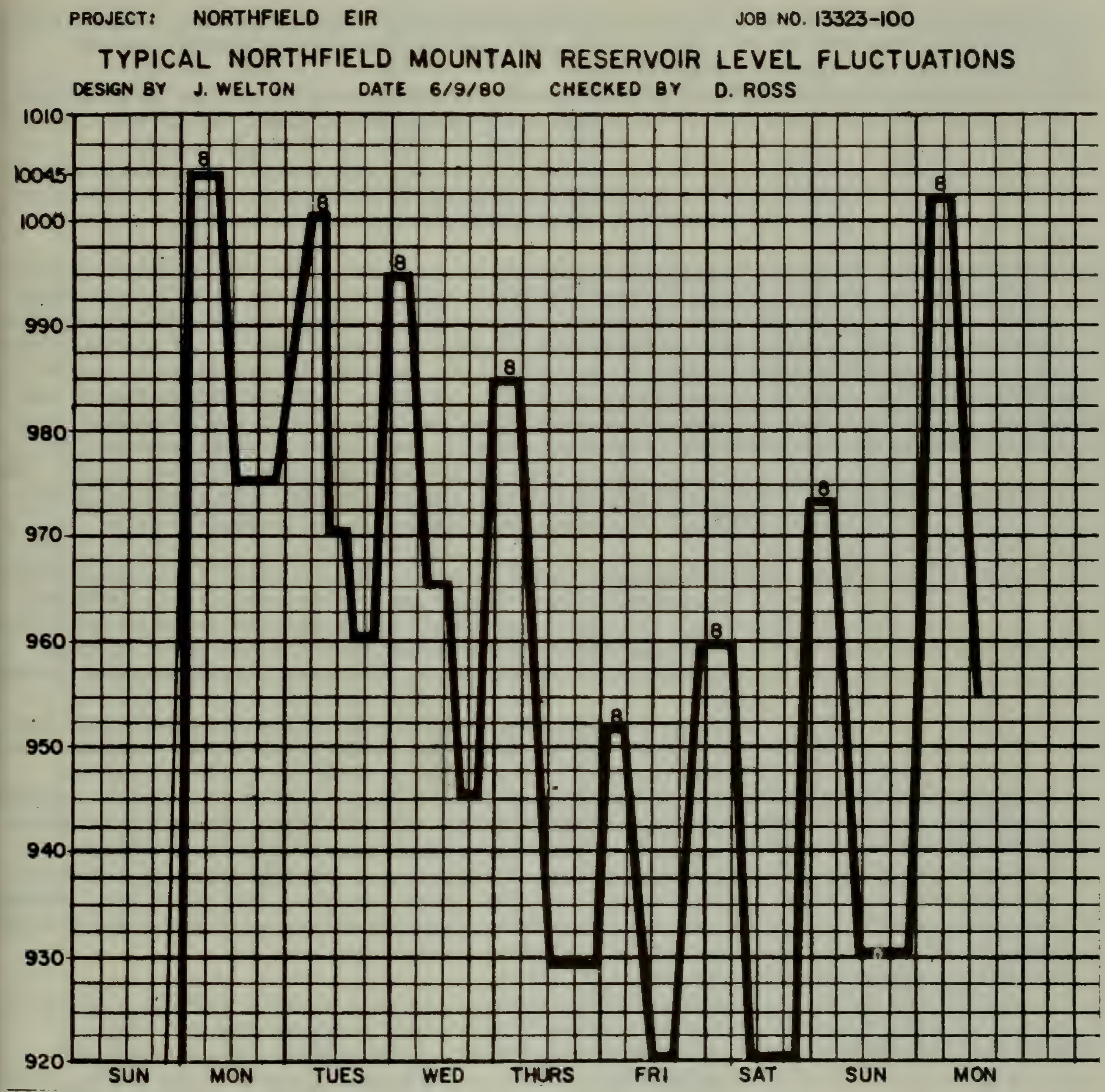
PROJECT: NORTHFIELD EIR
JOB NO. 13323-100
TYPICAL NORTHFIELD MOUNTAIN RESERVOIR LEVEL FLUCTUATIONS
DESIGN BY J. WELTON
DATE 6/9/80
CHECKED BY D. ROSS
1010
10045
1000
990
980
970
960
950
940
930
920
SUN
MON
TUES
WED
THURS
FRI
SAT
SUN
MON

Figure 1

to schedule more off-peak time for pumping than if power was transmitted to another system.

- If power is transmitted to another utility company, then scheduling of peak and off-peak power for pumping of NMR to QR water would be more difficult and use of the 1150 acre-feet of water would be subject to close coordination between the MDC and Northeast utilities.

The NMR power station does shut down for maintenance when one of the Northeast Utilities nuclear plants shuts down for refueling, as is the situation for the spring of 1980. It is desirable to shut down the pumping operations during a period when a nuclear facility is refueling or out of service because off-peak power costs increase due to the loss of nuclear power generation. If the refueling cycle occurs regularly during the spring freshet seasons, it could impair pumping to NMR for flood skimming to QR. The past history for the nuclear station refueling has indicated that refueling occurs in an irregular cycle.

NMR power station controls Turners Fall No. 1, Northfield, Cabot and Gardner Falls power stations. It is feasible that the NMR to QR tunnel power station would be controlled from NMR also, in the event that the new power station would return power to the Northeast Utilities power system.

Present operations require that the entire NMR power station and NMR be dewatered every 5 years for inspection and maintenance. This normally does not occur during the spring freshet flow season and lasts 4 to 6 weeks. Normal maintenance is one unit at a time and scheduling of maintenance is when one of the nuclear plants is refueling. These maintenance inspections are scheduled to coincide with a nuclear power plant shutdown for refueling. Northeast Utilities also controls Millstone 1 and 2 and Connecticut Yankee nuclear power stations.

Western Massachusetts Electric Company (WMEC), a subsidiary of Northeast Utilities, operates the NMR facility. The facility has 4 units for a total of 1,000,000 KW generation (4 units of 250,000 KW each). The total energy availability with a full reservoir is 10,250,000 KW hr. Pumping capacity is 12,000 cfs (3,000 cfs each for 4 units) The NMR facility can generate at one half of the rated unit output, but the pumping operation requires that the rated unit power of 250 MW be available for each pump turbine unit in operation.

Full reservoir elevation is 1004.5 feet (including the additional 4-feet) and the lowest operating elevation is 920 feet.

The lower reservoir on the Connecticut River, Turner Falls to Vernon Dam, ranges from a normal maximum elevation of 185 feet to a normal minimum elevation of 176 feet. The net operating generation head is 825 feet maximum and 720 feet minimum. The pumping net head is 840 feet maximum and 730 feet minimum.

The following responses are in reference to the questions posed above for each option:

1. Power can be generated. With a selected NMR to QR tunnel diameter of 10 feet for the power generation alternative and a reservoir elevation ranging between 1004.5 feet and 920 feet, the size of a power generation facility would be 18,000 kilowatts (or 18 MW). Midrange development is considered between 5 MW and 15 MW. Large hydropower developments are 15 MW and greater.

2. There would be a return on capital investment from revenue of power sales.

3. The powerhouse would be on the south bank of the Millers River.

4. An existing mill or facility cannot be used for power generation.

5. See answer 4 above.

6. Preferably power would be sold directly back to Northeast Utilities (NU). A power transmission line would be constructed from the new NMR to QR tunnel to the existing NMR powerhouse switchyard. If this is not practical then arrangements would have to be made with a local power company. The cost of the new NMR to QR power facility would be partially offset by the gain from sale of peak power versus the cost of off-peak pumping power. It is possible that generated power could be sold to MMWEC-Miller's River Project communities.

7. Licensing would be required for a new power station. Connection directly back to the Northeast Utilities system would minimize licensing procedures. The power station would be owned by the Metropolitan District Commission (MDC). Operation of the power station could be by MDC, NU or MMWEC. Licensing would be obtained by the owner.

8. Water is pumped from the Connecticut River to NMR. Water would not need to be pumped into the QR conduit.

9. There is presently off-peak power available for pumping and projections for the future indicate that there will be off-peak power available although specific quantities cannot be quoted. Off-peak power for the entire pumping requirement for NMR to QR flow would not be available every day of the week. Therefore, some pumping would be done during periods when power was delivered to the pumping units at costs above base load costs. It is possible that periods for skimming pumping and generation will overlap. Scheduling for pumping and generation will become an important factor. The present operating scheme for the Northfield powerhouse is irregular. Generation schedules in the new powerhouse in the NMR to QR tunnel must be worked out by the MDC, NU and the operator of the powerstation (if it is not MDC or NU). This item must be addressed in later phases of this study.

10. There is and would be pumping power available.

11. Since the NMR to QR flow is obtained from flood skimming above 17,000 cfs as measured at Montague there should be little effect to existing or planned generation facilities along the river.

12. It appears that there would be no effect on MMWEC.

13. It has been assumed for this phase that ozone treatment would be used.

<u>Miller's River</u>

The Miller's River diversion would be to Quabbin Reservoir. Water would be diverted by flood skimming.

1. Based on the size of the tunnel proposed by previous studies and the available head, power could not be economically generated. If the tunnel size is increased, the cost of the size increase would make the scheme even less economical.

2. There would be no revenue return on power generation.

3. No powerhouse would be constructed.

4. No mill or factory is in a suitable location from proposed diversion site for any power generation.

5. No arrangements would be made for power generation.

6. No power would be available to be sold.

7. No licensing would be required.

8. Water would flow by gravity flow into a diversion conduit.

9. It appears that pumping is not required.

10. See answer 9 above.

11. It may have an effect on any hydropower projects planned downstream on Millers River. Future study is required for this item.

12. This may affect the MMWEC program for possible power generation on the Miller's River at the following sites:

    a. Miller's Falls Two at Erving

    b. Erving Paper Mill at Erving

    c. Miller's Falls One at Erving

    d. Farley Paper Mill at Erving

    e. Wendell Depot at Erving

    f. Tully Lake at Athol

    Maximum available generation periods for these small hydropower sites would coincide with the spring freshet season and the skimming may impact the planned available recoverable energy at these sites.

13. It has been assumed for this phase that ozone treatment would be used.

Merrimack River

Flood water of the Merrimack River would be skimmed, treated and piped to an existing MDC conduit.

It is assumed that water would be taken by flood skimming and that a suitable site for an intake structure can be found. The site for this study has been tentatively selected on the south bank of the Merrimack River below Tyngsboro and above Pawtucket Dam.

1. Power could not feasibly be generated because there would not be enough head variation to allow generation.

2. No return on capital investment is feasible.

3. No new powerhouse would be constructed.

4. Power generation is not feasible.

5. See answer 4. above.

6. See answer 4. above.

7. No licensing would be required.

8. For this option water would be pumped from the river into a pipeline.

9. For this option, base power for pumping probably could not be obtained because of the short duration of the pumping period and the power demand that would be necessary. Pumping would be required 24 hours a day during pumping periods.

10. There is pumping power available but not base load power.

11. This skimming scheme may have an effect on the proposed facilities at Lowell and Lawrence. (See bibliography.)

12. The Pawtucket Dam-Lowell Hydro Project may be affected by skimming upstream from Lowell. The Moores Falls Project in Manchester, New Hampshire would not be affected.

13. It has been assumed for this phase that water treatment would be required.

<u>Ground Water Sources</u>

The available and feasible ground water sources are identified in other parts of this report. The following sources would require pumping facilities:

1) Dedham Avenue, Needham

2) Newton Water Works, Needham

3) Charles River Wells, Waltham

4) Rosemary Brook, Wellesley

5) Lake Cochituate Wells, Framingham

6) Buckmaster Pond, Westwood

Power usage for these sources and operation costs for these sources are shown in Table 1. Capital costs are included in the Cost Estimates section of this report.

Local Abandoned Surface Water Sources

The available and feasible surface water sources are identified in other parts of this report. The following sources will require pumping facilities:

1) Chicopee River Canal, Chicopee

2) Codey Brook and Morton Brook Reservoir, Chicopee

Power usage for these sources and operating costs for these sources are shown in Table 1. Capital costs are included in the Cost Estimates section of this report.

Plymouth Aquifer

The Plymouth Aquifer has been identified as a potential source for developing ground water. Power usage for this source is indicated in Table 1. Capital costs and operating costs are included in the Cost Estimates section of this report.

Desalinization

Power usage for desalinization is indicated in Table 1. Desalinization plant capital costs and operating costs are included in the Cost Estimates section of this report.

UNRESOLVED ISSUES/ FUTURE STUDIES

The following items are recommended for further analysis and evaluation in later phases of this study.

- Review Northeast Utilities Company data on pumping operation history and evaluate how to schedule pumping operations at a new Northfield Mountain Reservoir to Quabbin Reservoir powerhouse in coordination with Northfield Mountain Reservoir pumping operations. This study would include an analysis of periods of peak and off-peak power demands and how to apply dollar rates over the operating curve.

- Develop operating characteristics of Northfield Mountain Reservoir power facilities and schedule of operations for a yearly cycle from past history and projections for the future.

- Evaluate schemes for distributing the Northfield to Quabbin power. Schemes for delivering power to the Northeast Utilities Company system, to MMWEC and to local utilities would be studied. An overall system diagram would be prepared.

- Study the effect of river flood skimming schemes on all other generating facilities, existing or planned, along each river which is being evaluated for diversion.

- Prepare cost analyses for amortization of all new permanent structures and pumping facilities included in this study.

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APPENDIX 1

DEVELOPMENT OF ENERGY COSTS FOR NORTHFIELD EIR

The following data was obtained from the Massachusetts Electric Company:

1. Type of fossil fuel used for generation:

   -#6 oil (2.2% sulphur content) - 2100 MW

   -Coal - 500 MW

   -Natural gas - 50 MW

   -For peak demand: Jet engine gas turbine using #2 oil; Diesel engines; and pumped storage hydro.

   -For intermediate load demand #6 oil is used.

2. Energy equivalents:

   -#6 oil -149,000BTU/gallon

   -Coal - 13,000 BTU/lb.

3. Average cost of fossil fuel (January through April 1980)

   -Oil - $18/Barrel

   -Coal - $50/Ton or $12.25/Barrel

   -Natural gas - $ 3/1000 cu. ft. or $19-20/Barrel

4. Energy cost - Consumer monthly billing is done according to the following formula:

   Monthly billing = A + B + C

   A - Composite fuel adjustment cost
   Composite fuel adjustment is determined by the utility company on a quarterly basis and is approved by the Department of Public Utilities, Massachusetts. This cost is determined by the cost of fuel consumption for KWH generated in a month and is the average of all modes of demands, i.e. offpeak, peak and intermediate demand. Cost is given in mil/KWH.

B - Basic Demand Charges

This varies from customer to customer and is according to classification. For large industrial loads Classification H rate is used and for small industrial loads Classification G rate is used.

1) For classification H - max demand of:

i)	500 KW or less	-	\$830/month
ii)	In excess of 500 KW,	-	\$ 1.57/KW

2) For classification G - max demand less than 500 MW:

i)	5 KW	-	\$21.20
ii)	next 5 KW	-	\$ 2.36/KW
iii)	next 15 KW	-	\$ 2.01/KW
iv)	next 75 KW	-	\$ 1.87/KW
v)	in excess of 100 KW	-	\$ 1.73/KW

C - Energy Consumption Cost

1) For Classification H:

-up to 50,000 KWH	-	26.9 mil/KWH
-next 50,000 KWH	-	23.92 mil/KWH
-in excess of total 100,000 KWH	-	20.85 mil/KWH
-in excess of 200 hour x Demand	-	19.69 mil/KWH
-in excess of 300 hour x Demand	-	15.06 mil/KWH
-in excess of 400 hour x Demand	-	14.04 mil/KWH
-in excess of 500 hour x Demand	-	13.52 mil/KWH

2) For Classification G:

-up to 500 KWH	-	39.01 mil/KWH
-next 500 KWH	-	31.42 mil/KWH
-next 4,000 KWH	-	28.64 mil/KWH
-next 5,000 KWH	-	26.05 mil/KWH

- next 40,000 KWH - 25.12 mil/KWH
- next 50,000 KWH - 23.31 mil/KWH
- in excess of the above to 100,000 KWH - 21.76 mil/KWH
- in excess of 200 hr x Demand - 20.75 mil/KWH
- in excess of 300 hr x Demand - 19.68 mil/KWH
- in excess of 400 hr x Demand - 16.66 mil/KWH

5. Typical Example for classification H

700 KW maximum demand

250,000 KWH energy consumption

Billing Charges (monthly charges) = (A+B+C)

A - Fuel Adjustment Cost (presently 26.59 mil/KWH) $\frac{26.59}{1,000} \times 250,000$ = $6,647

B - Demand Charges

(i)	for 500 KW	= $ 830.00
(ii)	for 200 KW (in excess of 500 KW)	= $ 314.00
		$1,114.00

C - Energy Charges

(i)	50,000 KWH @ 26.90 mil/KWH	= $1,345.00
(ii)	next 50,000 KWH @ 23.92 mil/KWH	= $1,196.00
(iii)	next 40,000 KWH @ 19.69 mil/KWH	= $ 834.00
(iv)	next 70,000 KWH @ 19.69 mil/KWH (in excess of 200 hour x Demand therefore the rate of 19.69 mil/KWH is applied)	= $1,378.80
(v)	next 40,000 KWH @ 15.06 mil/KWH (in excess of 300 hr x Demand)	= $ 602.40
		$5,355.70

Total Cost = A + B + C = $13,147.20

Charges/KWH = $\frac{13,147.20 \times 100}{250,000}$ = 5.259 Cents/KWH

or

52.6 mil/KWH

6. Base load units generation (April through June 1980):

   -If oil is used for all base load generation then based on full load rated capacity the fuel adjustment cost is 26-27 mils/KWH (estimated)

   -If coal is used for all base load generation then based on full load rated capacity the fuel adjustment cost is 17-18 mils/KWH (estimated)

   -If all natural gas (Data not available.) This option has not studied by the utility company. However based on 50 MW old plants is 20 mil/KWH.

   -For peak demand the utility company is using:

   -Jet engine gas turbines #2 oil

   -Pumped storage hydro

   -Diesel (for diesel fuel the cost reaches 60 mils/KWH)

   -For intermediate load demand generation fuel adjustment cost is 31 mil/KWH (450 MW unit) using #6 oil. Sometimes for intermediate load demand diesel is also used raising the generation cost to 60 mil/KWH.

Northfield EIR July 16, 1980

Response to NCAC Comments on Power Analysis Memorandum

The following numbers correspond to the numbered items in the NCAC July 14, 1980 memorandum (copy attached).

1. Incorporated comment into final draft. (Incorp. F.D.)

2. Incorp. F.D.

3. We agree. This EIR study considers diversions to be only during the spring freshet season.

4. We have no documentation regarding regularity of nuclear refueling periods, but past experience indicates that refueling is irregular and is based on usage. For example, if heavy demands are placed on nuclear plants because of unavailability of fossil fuels or water power then refueling will be more often. In our discussions with Northeast Utilities Company (NU) this item was discussed and they agreed but have not given us any past history records of the refueling occurrences as we requested.

5. Answered in report.

6. There is no documentation available. NU has not furnished us with any of their documentation to date as requested.

7. Incorp. F.D.

8. There is no documentation available for the statement, but it was made based upon the fact that since Moores Falls is upstream, then a downstream diversion will not effect it.

9. Both statements have been deleted from report. The mineral by-product referred to was salt.

10. We agree. This EIR study considers diversions to be only during the spring freshet season.

11. Our method is cite name and reference upon a specific quotation from a reference. No such specific quotations are included.

12. These items were not studied for power consumption or generation.

BECHTEL INCORPORATED

JUL 15 1980

RECEIVED
3:45 PM

MEMORANDUM

TO: Patricia B. Corcoran, MDC, and Adel Foz, WPRM
FROM: Marjorie Holland Sackett, NCAC M.H.S.
DATE: 14 July 1980
SUBJECT: NCAC comments for Bechtel's Draft Technical Memorandum on Power Analysis

1. page 1, Power Analysis. Since the memo discusses power costs and availability for the Merrimack and Millers Rivers alternatives, they should be included in the first paragraph.

2. page 2, Questions that need to be answered, #12. The first time an abbreviation is used in a Memo, it should be spelled out (i.e. MMWEC and NERBC).

3. page 3, Alternatives, paragraph 1. The way present legislation is worded, a diversion would not be restricted to "the spring freshet season."

4) page 3, Alternatives, paragraph 4. NCAC would like to see documentation for the statement "the past history for the nuclear station refueling has indicated that refueling occurs in an irregular cycle." The historical refueling cycle for Northeast Utilities plants should be thoroughly investigated.

5) page 4, paragraph 1. How long does it take and during what time of year is NMR dewatered "for inspection and maintenance."

6) page 5, question 9. Where is the documentation for the statement that "projections for the future indicate that there will be off-peak power available"?

7) page 7, Merrimack River, top of page. The use of the word "will" is inappropriate. The sentence should read, "The Merrimack River would be diverted to an existing MDC conduit."

8) page 7, question 12. What documentation is available for the statement, "The Moores Falls Project in Manchester, New Hampshire would not be affected"?

9) page 8, Desalinization. What "fossil fuel power station" is envisioned? The "investment return on the mineral by-products of the desalinization process" should be explained.

10) page 9, third recommendation. It is not clear from present legislation that a diversion would occur only during the spring.

11) Bibliography. It would be helpful to the reader if references could be cited throughout the body of the MEMO by author's last name and date of publication.

12) Table 1, Alternate Supply Sources Power Comparison. Where will consideration be given to the Water Conservation, Watershed Management, and No Action Alternatives?

NEW ENGLAND RESEARCH, INC.
15 SAGAMORE ROAD
WORCESTER, MASSACHUSETTS 01605
TELEPHONE: (617) 752-0346

TECHNICAL MEMORANDUM

TASK 1.4-2

WATER QUALITY -
RESERVOIRS, SURFACE AND GROUNDWATER SUPPLIES
NORTHFIELD EIR

REPORT NO. NER-144-01

SUBMITTED TO

WALLACE, FLOYD, ELLENZWEIG, MOORE, INC.

JULY 11, 1980

Environmental Consulting Services

New England Research, Inc. (NER) has conducted a Phase I study of the water quality issues associated with various alternatives included in the Northfield EIR Project. This section summarizes the findings contained in the technical memorandum report on the Phase I study.

The general approach of the Phase I study included (1) defining the major water quality issues associated with each alternative, (2) compiling the relevant data and information available, (3) assessing the adequacy of the data in addressing the issues, (4) and making recommendations for approaches for future, Phase II studies.

The key water quality issue for all alternatives centered on the public health implications of the alternative actions. Current Federal Regulations and Massachusetts standards define the parameters and standards required to evaluate public drinking water supplies. Other water quality issues have to do with potential water quality changes in both reservoir and riverine systems which would be affected by the various alternatives.

Table 1-1 provides a summary of the evaluation of the information required for the water quality impact assessment. The necessary information has been summarized and evaluated as to its adequacy for the assessments in Phase II. All the evaluations summarized in Table 1-1 relate back to the key water quality issues.

The Phase I study also provided recommendations for approaches to subsequent efforts. Table 1-2 is a summary of recommended approaches to future efforts.

Table 1-1. Summary of Evaluation of Information Required for Water Quality Impact Assessment.

Alternative	Necessary Information	Adequacy Status: Adequate	Adequacy Status: Inadequate
No Action	Water Quality Data on MDC Reservoirs	X	
	Morphometric and Bathymetric Data on Reservoirs	X	
	Projected Fluctuations in Reservoir Levels		X
Northfield Flood Skimming	Water Quality Data on Connecticut River		X
	Water Quality Data on Northfield Reservoir	X	
	Water Quality Data on Quabbin Reservoir	X	
	Engineering Data on Skimming	X	
	Hydrodynamic Studies		X
Connecticut Tributaries Flood Skimming	Water Quality Data on Tributaries		X
	Water Quality Data on Quabbin Reservoir	X	
	Engineering Data on Skimming	X	
	Hydrodynamic Studies		X
Quabbin Watershed Management	Vegetation Modification Program		X
	Types of Soil		X
	Types of Vegetative Cover		X
	Water Quality of Inflow Streams	X	
Upper Sudbury Watershed	Water Quality Data on Reservoir	X	
	Water Quality Data on Rivers		X*
	Engineering Data on Operation of the Sudbury System	X	
	Data on Reservoir Levels and River Stage Fluctuations	X	
Abandoned and Reserve Sources	Identification of Specific Water Supplies (Sources)		X
	Water Quality Data		X
	Engineering Data		X
Groundwater-Plymouth Aquifer	Identification of Specific Water Supplies (Sources)		X
	Water Quality Data		X
	Engineering Data		X

* More recent information is being reviewed by other MDC consultants.

Table 1-2. Summary of Recommended Approaches for Future Efforts.

Alternative	Recommended Approaches for Future Efforts
No Action	Make predictions of future reservoir levels over several decades, including extended drought conditions. Estimate changes in water quality related to changes in reservoir levels.
Northfield Flood Skimming	Acquire additional water quality data on Connecticut River. Apply conceptual model to impact assessment process. Consider several alternative approaches to assessing water quality impacts. Coordinate hydrodynamic studies.
Connecticut Tributaries Flood Skimming	Acquire additional water quality data on tributaries if needed. Apply conceptual model to impact assessment process. Consider several alternative approaches to assessing water quality impacts. Coordinate hydrodynamic studies.
Quabbin Watershed Management	Update 1971 vegetation data using recent aerial photos, timber sale records and field reconnaissance. Conduct a reconnaissance-type soil survey on unmapped areas. Conduct limited water quality sampling in inflow streams if needed.
Upper Sudbury Watershed	Coordinate efforts with Sudbury EIR project.
Abandoned and Reserve Sources	Conduct water quality surveys of selected supplies within MWD. Identify specific surface water resources outside MWD. Conduct additional water quality surveys on these other water supplies outside MWD.
Groundwater - Plymouth Aquifer	Identify specific groundwater resources outside MWD. Conduct water quality surveys as necessary on these groundwater supplies.

This is a technical memorandum which summarizes the findings of studies conducted by New England Research, Inc. (NER) during Phase I of the Northfield EIR Project.

NER is providing environmental consulting services to Wallace, Floyd, Ellenzweig, Moore, Inc. (WFEM), and is assessing the water quality and ecology of reservoirs and other, selected water resources included in the scope of the project. This is the technical memorandum on the water quality segment of the study. A separate technical memorandum (NER-144-02) describes the ecological segment of the study.

Seven alternatives are included in this part of the study. These alternatives include the following:

- No Action
- Northfield Flood Skimming
- Connecticut Tributaries Flood Skimming*
- Quabbin Watershed Management
- Upper Sudbury Watershed
- Abandoned and Reserve Sources**
- Groundwater - Plymouth Aquifer**

Each alternative has been evaluated with a standard procedure. This procedure is based upon a series of five key questions:

1. What are the major environmental issues?
2. What is the necessary information to evaluate the issues?
3. What is the existing information available for evaluation?
4. Is the existing information adequate to evaluate the issues?
5. What is the approach recommended for future studies?

The organization of this technical memorandum reflects these key questions.

* In the Scope of Work, this alternative was named Connecticut River Tributaries.

** These two alternatives make up the alternative named in the Scope of Work as Groundwater and Surface Water in User Communities, Possible Future Communities, Metropolitan Boston, and Plymouth County.

3A. INTRODUCTION

The No Action Alternative is a key element in the assessment of the Northfield EIR Project. It provides a baseline condition against which the other alternatives may be assessed.

The No Action Alternative, which extends through the year 2020 (WFEM, 1979) has the potential to have direct and indirect impacts upon the parameters of the physical, biological, and social environments of the project area, and the interrelationships which exist between these environments. Conditions prevailing during this period will be estimated from supply and demand projections.

3B. MAJOR ISSUES

The major water quality issues of the No Action Alternative are the effects that possible drawdowns in water level will have upon the water quality of the Quabbin, Wachusett and Sudbury Reservoirs, if demand exceeds supply.

3C. NECESSARY INFORMATION

In order to effectively evaluate the impacts of the No Action Alternative, it will be necessary to have the following data:

- Water quality data for the Quabbin, Wachusett and Sudbury Reservoirs, particularly with respect to the Federal and State drinking water standards (see Appendix 11A).
- Data on possible water drawdowns at each of the reservoirs.
- Information on the morphology (form and structure) and bathymetry (depth measurements) of each of the reservoirs.
- Projected evaluations of changes which may occur in the water level of the reservoirs over the time period of the no action condition (through the year 2020).

3D. EXISTING INFORMATION

There is a substantial amount of water quality data available for the Quabbin, Wachusett and Sudbury Reservoirs. Over thirty years of data on a wide variety of physical, chemical and biological parameters exist for Quabbin and Wachusett Reservoirs. In addition, approximately ten years of water quality information is available for the Connecticut River at the intake for the Northfield Reservoir, and at Northfield Reservoir. Pertinent water quality data are referenced under specific alternatives: Northfield Flood Skimming, Connecticut Tributaries Flood Skimming, Quabbin Watershed Management and Upper Sudbury Watershed.

Data on water level fluctuations are available and consistent with respect to the different reservoirs. Information is available on changes in the reservoirs' surface elevations during the 1960's (drought period) and during the period of above normal precipitation in the 1970's (Personal Communication, MDC, 5/1/80). Pertinent literature on water level fluctuations for the Quabbin and Wachusett Reservoirs is as follows: Erickson et al., 1975; Miner, 1974; and Higgins, 1968.

Baseline morphologic and bathymetric data are available for the Quabbin, Wachusett and Sudbury Reservoirs. There is information on the configuration and depth of the reservoirs from their conception and construction to the present (MDC, 1973; Hecker and Yale, 1971; WFEM, 1978; McCann and Daly, 1972a, 1972b; McCann et al.,1972a, 1972c; Higgins, 1968; CE Maguire, Inc., 1979; and Coffin and Richardson, Inc., 1980).

There is considerable information available which reviews and/or analyzes past data on water consumption and water level fluctuations, and which outlines projected changes and needs within the MDC water supply system. Pertinent literature is as follows: MDC, 1979; FPC, 1976; WFEM, 1978; NER, 1973; Higgins, 1968; NER, 1978; MAPC, 1978; Erickson et al., 1975; CE Maguire, Inc. 1979; and Coffin and Richardson, Inc., 1980.

3E. EVALUATION OF INFORMATION

A preliminary analysis of the existing water quality information indicates that there are sufficient data on water quality within the Quabbin, Wachusett and Sudbury Reservoirs with respect to public health and the Federal and State drinking water standards. In addition, there are adequate analytical data available on reservoir level fluctuations, and the morphology and bathymetry of the aforementioned reservoirs, when coupled with the water quality information, to predict changes in water quality as reservoir levels fluctuate.

3F. RECOMMENDED APPROACH

No additional field work or laboratory work is recommended for the No Action Alternative.

However, it will be necessary to make future predictions of water levels in the MDC reservoirs under a variety of hydrologic scenarios. Therefore, it is recommended that future water levels for Quabbin Reservoir, Wachusett Reservoir and Sudbury Reservoir be projected under a series of hydrologic conditions through the year 2020. A scenario of a period of extended drought, such as occurred in the 1960s, is especially recommended for one of the projections with this alternative. The projected changes in the water levels should then be used to estimate changes in water quality.

4A. INTRODUCTION

One of the alternatives for augmenting the water supply of the MDC system includes skimming water from the Connecticut River into Northfield Reservoir for transfer into Quabbin Reservoir during periods of high flood flow (flow exceeding 17,000 cfs in the Connecticut River).

This alternative was included in the Northeastern United States Water Supply (NEWS) Study by the U.S. Army Corps of Engineers (U.S. ACE), (NER, 1972a; U.S. ACE, 1973; Erickson et al., 1975). The Northfield Reservoir currently is a pumped storage reservoir for the hydroelectric facility operated by Northeast Utilities.

The Northfield Flood Skimming Alternative has been studied by the New England River Basin Commission (NERBC, 1972), the Federal Power Commission (FPC) (now Federal Energy Regulatory Commission, 1976), and the Commonwealth of Massachusetts (WFEM, 1978, 1979).

4B. MAJOR ISSUES

The major water quality issue associated with this alternative is the public health impacts from the introduction of water from the Connecticut River into Quabbin Reservoir.

Transfer of Connecticut River water through Northfield Reservoir into Quabbin Reservoir will introduce riverine water of a lower quality into the MDC system. Such an introduction will have public health implications. It may also result in a potential loss of water quality in Quabbin Reservoir, and possibly Wachusett Reservoir. Quabbin and Wachusett are classed as "A", and the Connecticut River is classed as "B" in the Massachusetts Water Quality Standards (Massachusetts Division of Water Pollution Control (DWPC),1978).

4C. NECESSARY INFORMATION

The data necessary to evaluate the major issues are the water quality parameters and standards currently required to evaluate public drinking water supplies. These parameters include:

- physical data
- inorganic chemicals
- trace metals
- trace organic chemicals (including pesticides)
- radioactivity data
- microbiological data

These parameters are included in both the Federal and Massachusetts standards. Appendix 11A provides additional details.

Another major water quality issue relates to potential losses in water quality in relation to aquatic ecology and aquatic habitat. Changes in water quality in Quabbin Reservoir can also influence the other reservoirs in the MDC system. Such changes in turn could influence the aquatic ecology of the various reservoirs.

Water quality data for the Connecticut River, the Northfield Reservoir, Quabbin Reservoir and Wachusett Reservoir are needed. In addition, engineering data on the proposed operation of the Northfield facility will be required, including:

- amounts to be skimmed
- time frames of the skimming
- locations of inputs into Quabbin Reservoir

It will also be necessary to know what the hydrodynamics (water movements) within the reservoir will be during the skimming periods. Finally, it will be necessary to have an estimate of the residence time (how long the water mass stays localized in one place) for the water mass transferred into the reservoir.

Since Quabbin Reservoir is part of the MDC system, which includes Wachusett Reservoir and the Sudbury system, typical MDC operating data on flows among the reservoirs in the system will also be necessary.

It will also be necessary to have water quality data which are relevant to the aquatic ecology. Important parameters include the following:

- dissolved oxygen
- temperature
- pH
- turbidity
- dissolved solids
- nitrogen parameters
- phosphorus parameters

Additional details can be found in Appendix 11A of this report and in Appendix 11A of the ecology report.

4D. EXISTING INFORMATION

Existing information which is pertinent to the Northfield Flood Skimming Alternative includes those reports generated in the NEWS Study sponsored by the U.S. Army Corps of Engineers and the MDC (see Table 4-1). Subsequent to the NEWS Study, New England Research conducted an extensive water quality monitoring program for the MDC. The reports of this program include water quality data on the Connecticut River, Northfield Reservoir, Quabbin Reservoir and Wachusett Reservoir. The data include biological, chemical and physical parameters.

Table 4-1. Summary of Selected Data and Information on Quabbin Reservoir

Technical Reports and Data Sources	Types of Data and Information
Reed, 1947 Erickson and Reynolds, 1969 Reynolds *et al.*, 1970 Massachusetts Division of Fisheries and Game, 1970 New England Research, Inc., 1972a, 1972b, 1973, 1974, 1975a, 1975b, 1976, 1977, 1978, 1980 Metropolitan District Commission Files	Water quality data, from various stations, including biological, chemical and physical parameters.
New England Research, Inc., 1972a Corps of Engineers, 1973 Erickson *et al.*, 1975 Hecker and Yale, 1971	Engineering data, hydrodynamic data, and environmental impact assessment of flood skimmings into Quabbin Reservoir.
Erickson and Reynolds, 1969 Higgins, 1968 Higgins and Colonell, 1971	Thermal data and hydrodynamic studies.
New England Research, Inc., 1973, 1975a, 1975b Erickson and Camougis, 1974 Erickson and Clausen, 1975 Miner, 1974 Reynolds *et al.*, 1968 Rho *et al.*, 1969 Segal *et al.*, 1969	Research studies on heterotrophic bacteria, phytoplankton, field mixing studies, laboratory mixing studies, productivity and inundation of shoreline vegetation.
New England Research, Inc., 1977	Computerization of water quality data.

During the earlier studies on Quabbin Reservoir, hydrodynamic (water movement) studies were conducted by the Alden Research Laboratories of WPI. Both an analytical (mathematical) and and physical model were used to study the movement of water masses introduced into Quabbin Reservoir (Hecker and Yale, 1971).

Other reports available on Quabbin Reservoir are summarized in Table 4-1. Data on the Northfield Reservoir are available in a series of reports from New England Research, Inc. (e.g., 1978, 1980) and in Massachusetts Division of Fisheries and Game (1978). Data on the Connecticut River are being compiled by Normandeau Associates, Inc. in a separate report for this project.

4E. EVALUATION OF INFORMATION

Existing information on the water quality of Quabbin Reservoir is adequate for this alternative. It is also adequate for the Northfield Reservoir, although additional data collected at higher frequency may be desirable for the period of proposed flood skimming into Quabbin. The adequacy of the data base on the Connecticut River is being evaluated in a separate report by Normandeau Associates, Inc. In all cases, the data of primary relevance for evaluation are those related to drinking water standards (see Appendix 11A).

Previous hydrodynamic (water movement) studies of Quabbin Reservoir (NER, 1972a; Hecker and Yale, 1971), were conducted without considering the effects of thermal stratification and wind. Also, the studies were conducted at reservoir levels which simulated the effects of the earlier drought conditions. Additional hydrodynamic studies will be needed to supplement the earlier studies.

Sufficient engineering data exist from the NEWS Study reports (see Table 4-1). However, these earlier studies did not consider any current constraints imposed by the need to optimize the operation of the pumped storage facility. Consequently, any alternatives which will influence the proposed skimming will require additional engineering studies.

4F. RECOMMENDED APPROACH

The recommended approach is to apply a general, conceptual model which illustrates the impact assessment process. This conceptual model must show how the following information is integrated in the assessment process:

1. water quality data of the receiver system
2. water quality data of the donor system
3. water quality criteria and standards
4. engineering data

5. hydrodynamic data

An example of such a conceptual approach is shown in Figure 4-1.

Several alternative approaches may be used to evaluate the water quality impacts. One approach that is recommended is the use of the hydrodynamic studies. These studies will provide information on (1) residence times (how long given water masses remain generally localized), and (2) the degree of mixing. From these data simple dilutions can be calculated for various parts of the reservoir. The final concentrations of key parameters (see Appendix 11A) can then be compared with the water quality standards.

Many constituents in the water do not remain unchanged in the water column. Another approach which may be applied is based on a qualitative, multi-compartment model. Such an approach is recommended because it enables the prediction of the behavior of various water quality parameters (e.g., metals, pesticides).

These predictions have relevance to both the water quality and the aquatic ecology (see Report No. NER-144-02). Figure 4-2 is a diagram of a simple multi-compartment model of an aquatic ecosystem such as a reservoir.

Still another approach is based on a quantitative, dynamic model. The use of a computer model provides one approach to a quantitative model. A computer model may be based on a multi-compartment model such as that described above. It is important to note that no aquatic system has ever been studied sufficiently so that all kinetics (transfer functions) are fully known. Consequently, any quantitative dynamic model must be based on well defined assumptions. It is recommended that quantitative dynamic modeling studies of selected parameters be conducted only after the other approaches have highlighted specific public health and ecological problems.

Water quality changes in Quabbin Reservoir may be transmitted to Wachusett Reservoir. Consequently, it may be necessary to include an assessment of the water quality impacts on Wachusett Reservoir. In that case, the simple dilution model, the qualitative, multi-compartment model and possibly a quantitative, dynamic model are also recommended for analysis of water movement from Quabbin Reservoir into Wachusett Reservoir.

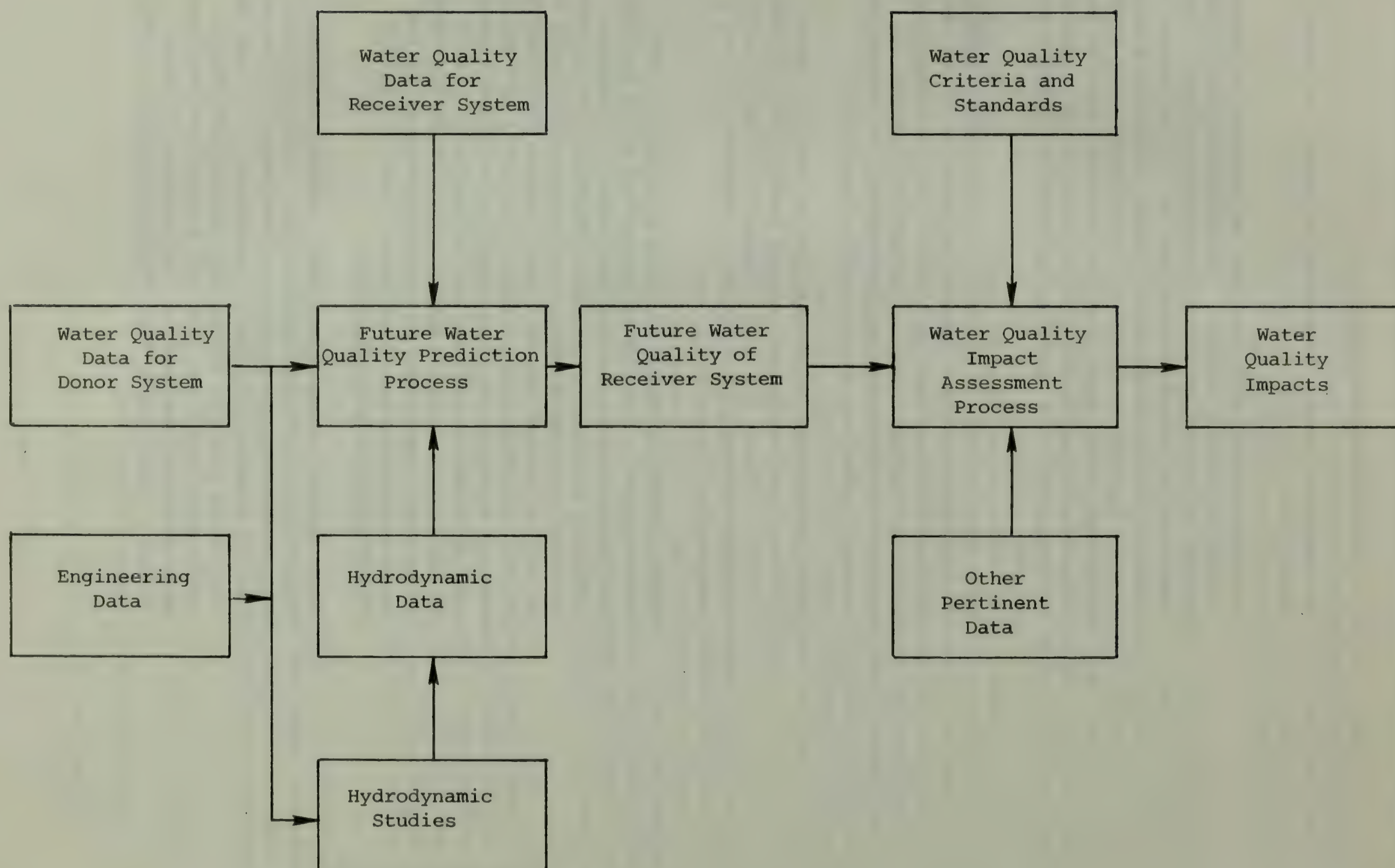

Figure 4-1. Conceptual Model of a Systems Approach to an Impact Assessment Process.

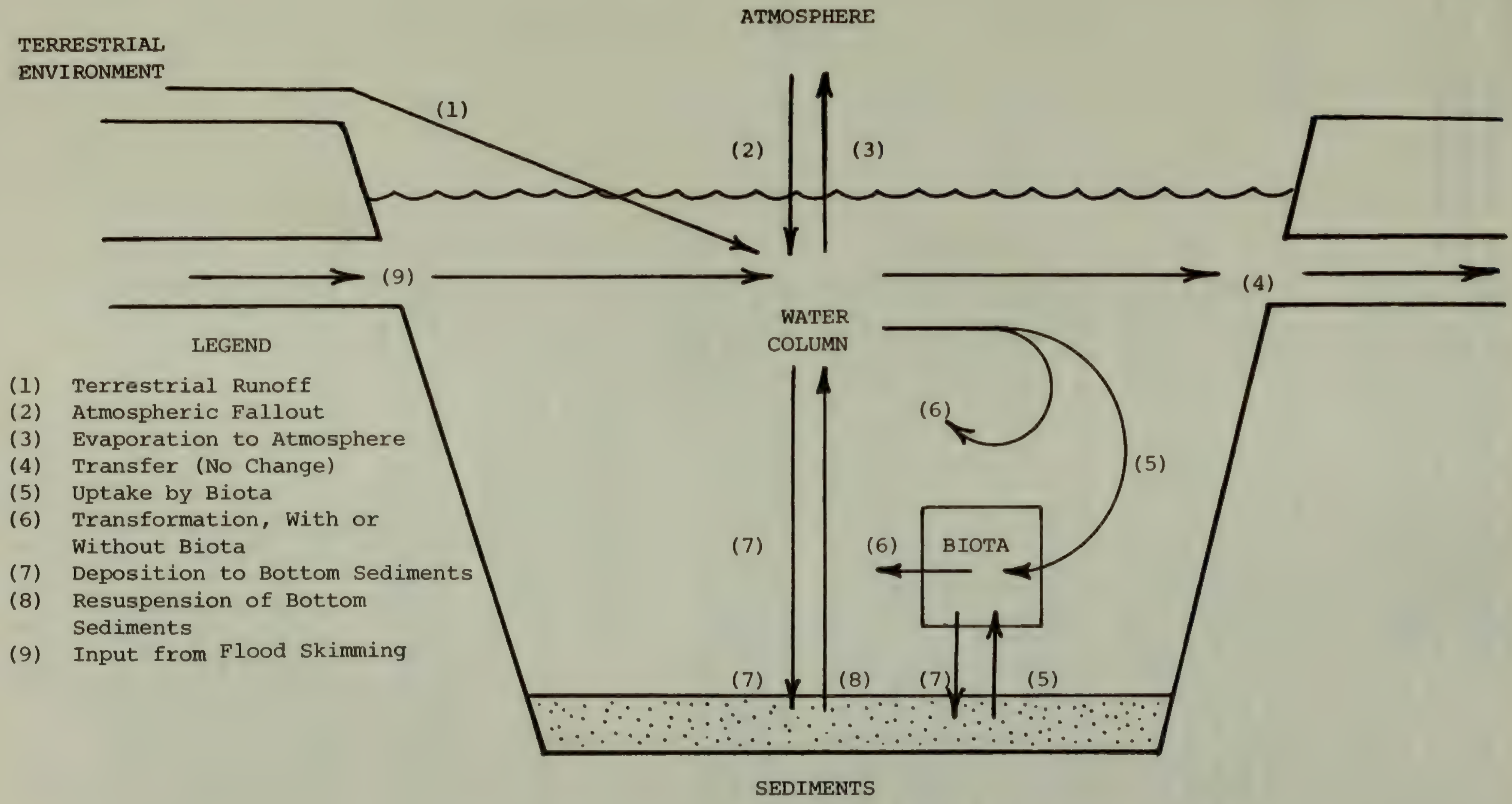

Figure 4-2. Diagram of a Multi-Compartment Model of an Aquatic System. (Modified after Erickson et al., 1975, 1978 and Camougis, 1980).

It is recommended that the hydrodynamic modeling studies be coordinated among the various consultants. In that way the engineering data inputs and the modeling study outputs will be optimized to the assessment of the public health issues.

5A. INTRODUCTION

Another alternative for supplementing the MDC water supply centers on the skimming of water from the tributaries of the Connecticut River into Quabbin Reservoir during periods of high flow. This alternative was included in the NEWS Study (see Section 4A) by the U.S. Army Corps of Engineers. The Millers River, in particular, was investigated in some detail by the study.

5B. MAJOR ISSUES

The major water quality issue for this alternative is similar to that with other alternatives which may introduce lower quality water into Quabbin Reservoir (see, for example, Northfield Flood Skimming). The major issue centers on the public health impacts from the introduction of waters from the Connecticut River tributaries into Quabbin Reservoir.

Another major issue relates to the potential losses in water quality in Quabbin Reservoir, and possibly Wachusett Reservoir. This is especially true over a long period of time (e.g., decades) after a number of skimming cycles. Both water supplies are now classed as "A" in the Massachusetts Water Quality Standards (DWPC, 1978). The Millers River basin is classed as "B" in the 1978 standards. Changes in water quality in Quabbin Reservoir and Wachusett Reservoir will influence the aquatic ecosystems of the reservoirs.

5C. NECESSARY INFORMATION

The data necessary to evaluate the major issues are similar to those for the Northfield Flood Skimming Alternative (see Section 4C). Water quality parameters currently required to evaluate drinking water supplies include:

- physical data
- inorganic chemicals
- trace metals
- trace organic chemicals (including pesticides)
- radioactivity data
- microbiological data

These parameters are included both in the Federal Regulations and the Massachusetts standards (see Appendix 11A for details).

Water quality data both for the potential donor systems (riverine waters) and for the potential receiver system (Quabbin Reservoir) are needed. In addition, data on the amounts of water, the seasons of the year, and the quantity of water proposed for skimming would be required. Finally, the hydrodynamic (water movement) patterns of the reservoir and the residence time (how long the water mass stayed in place) of the transferred water mass would need to be determined.

Aside from the water quality issues relating to public health, probable changes in the water quality of the MDC system need to be determined. Of particular relevance are those parameters which relate water quality to aquatic habitat and aquatic ecology. The types of data that are needed to evaluate water quality changes in relation to existing standards include the following:

- dissolved oxygen
- temperature
- pH
- turbidity
- dissolved solids
- nitrogen parameters
- phosphorus parameters

Additional details on water quality in relation to aquatic ecology are listed in Appendix 11A of this report and in Appendix 11A of the ecology report.

5D. EXISTING INFORMATION

Existing information includes the reports on the NEWS Study sponsored by the U.S. Army Corps of Engineers in cooperation with the MDC (NER, 1972a; U.S. ACE, 1973; Erickson et al., 1975). These reports include data on selected biological, chemical and physical parameters from both riverine and reservoir systems. Since these earlier studies, New England Research, Inc. has conducted additional water quality studie for the MDC for selected riverine and reservoir stations. Consequently, extensive water quality data on biological, chemical and physical parameters are available for Quabbin Reservoir (see Table 4-1).

The NEWS Study also included engineering data such as flows and volumes. Studies of hydrodynamics (water movements) were conducted by the Alden Research Laboratories of WPI on a physical model of Quabbin Reservoir (Hecker and Yale, 1971). Thermal data for various locations in the reservoir have been reported by Erickson and Reynolds (1969), Higgins (1968), and Higgins and Colonell (1971).

Quabbin Reservoir has been investigated through a series of limnological, microbiological and ecological studies during the 1960s and 1970s. A summary of the various studies is included in Table 4-1.

Since the earlier studies on the Millers River system (New England Research, Inc., 1972a; U.S. ACE, 1973; Erickson et al., 1975), other water quality data have been compiled by the U.S. Geological Survey (U.S.G.S.), (1976). Additional data on the tributaries are being compiled by Normandeau Associates, Inc. for this project.

5E. EVALUATION OF INFORMATION

The water quality data for Quabbin Reservoir are adequate for the assessment of this alternative.

Additional water quality data on the tributaries (e.g., the Millers River) may be required. This is especially true for water quality parameters of relevance to drinking water (see Appendix 11A).

The previous discussion on earlier hydrodynamic (water movement) studies also applies to this alternative (see Section 4E). The information needed to evaluate this alternative includes data from additional hydrodynamic studies for Phase II.

Sufficient engineering details exist in the NEWS Study to assess this alternative. However, any alternative skimming scenarios will require additional engineering studies.

5F. RECOMMENDED APPROACH

The conceptual approach to assessing the impacts of water transferred into Quabbin Reservoir was described in Section 4F for the Northfield Flood Skimming Alternative. The same general approach is recommended for the Connecticut Tributaries Flood Skimming Alternative.

It is likely that the volumes transferred into Quabbin Reservoir from the Connecticut Tributaries Flood Skimming Alternative would be the same as those from the Northfield Flood Skimming Alternative. Consequently, it may be necessary to also include an assessment of the water quality impacts on Wachusett Reservoir. In that case, the simple dilution model, the qualitative, multi-compartment model and possibly a quantitative, dynamic model are also recommended for analysis of water movement from Quabbin Reservoir into Wachusett Reservoir (see Section 4F).

No additional field surveys are recommended for this alternative.

Finally, the previous recommendation for close coordination among the various consultants (see Section 4F) also applies to this alternative. Consequently, the recommended approach will require the coordination of engineering data, water quality data, and public health data. The whole, conceptual approach is based on such coordination (see, for example, Figure 4-1).

6A. INTRODUCTION

6A1. BACKGROUND

A watershed (drainage basin, catchment area) is the land surface from which water flows to a given point on a water course (Pereira, 1973). Watershed management is management of land surfaces within a watershed boundary to meet water-related and other objectives. The MDC has always practiced watershed management on their lands. In the earliest days, their objective was protection of high quality water supplies. They restricted public access and planted pine plantations on unused farm land to reduce erosion. Over the years the objectives have broadened to include objectives of increased water yield, improvement of forest quality, maintenance of healthy wildlife populations, and protection of an aesthetically pleasing landscape (Spencer and Walker, 1972), as well as protection of high quality water supplies. Additional emphasis has been recently placed on the water yield objective (MDC, 1979). As outlined below, the Quabbin Watershed Management Alternative will focus on increasing water yield through watershed management.

6A2. DESCRIPTION OF THE ALTERNATIVE

The Quabbin Watershed Management Alternative for increasing the MDC water supply is intensive vegetation management on MDC lands to reduce evaporation losses from the watershed and thereby increase water yield. The three land areas under consideration as specified by the Scope of Work are:

- Quabbin Reservoir watershed (upstream of Winsor Dam).
- MDC land in the Ware River watershed (upstream of Shaft 8 diversion in Barre).
- MDC land in Wachusett Reservoir watershed (upstream of Clinton Dam).

Several possible vegetation management scenarios will be considered in Phase II. These scenarios may include:

- Reducing the leaf cover (density) of existing vegetation types. Several different density levels may be evaluated.
- Replacing the existing vegetation types with another type of vegetation that uses less water.

Vegetation management affects other resources in addition to modifying water yields. For example timber products and wildlife populations including rare and endangered species, are two resources that may be enhanced or diminished, depending on the particular management scenario.

The effectiveness of vegetation management for increasing water yield is limited by constraints imposed by other mandated uses of a watershed such as recreational use, scientific study, administrative use, rights-of-way for highways and powerlines, legislative restrictions, etc. A vegetative management plan for increasing water yield has to consider the other resources and uses of the watershed, and consider a specific scenario of objectives. However, major issues can be identified for water quality in relation to vegetation management even without specific objectives being available.

6B. MAJOR ISSUES

6B1. CHANGES IN INFLOW WATER QUALITY

A major water quality issue for the Quabbin Watershed Management Alternative is the possible change in water quality of streams flowing into the reservoirs. Changes in quality could result from the activities necessary to produce vegetation changes such as logging and site preparation. Parameters that might be affected include temperature, turbidity and nutrient levels of such nutrients as nitrogen and phosphorus. Such changes may have public health implications and may also have effects on fisheries and other aquatic life.

6B2. SUBSEQUENT CHANGES IN RESERVOIR QUALITY

A second major issue that follows directly from the first is the change that may occur in water quality in the reservoirs. Reservoirs have natural treatment processes that may be overloaded if inflowing water quality declines too much. Such overloads may result in lowered water quality in the reservoirs with effects on public health and fisheries.

6B3. CHANGES IN WARE RIVER QUALITY

A third issue also stems from the first. Changed water quality in the Ware River upstream from the Shaft 8 diversion may have effects downstream as well as on the water skimmed to Quabbin. Water quality changes as it affects public health and fisheries and other downstream uses is the issue.

6C. NECESSARY INFORMATION

6C1. VEGETATION

Information on the existing vegetation on the watersheds, including species, density, and location, is needed to make prescriptions for vegetation management. Species data is needed because different species use different amounts of water. Water use is also a function of leaf area. Density data, which is correlated with leaf area, is more readily available than leaf area data. Location of each stand is necessary for correlation with soils data. For predicting impacts from this alternative, the types of vegetation modification, the methods to be used and the vegetation resulting from modification have to be known.

6C2. SOILS

Soil type data is necessary for making estimates of water-holding capacity which is one component in prescribing vegetation management. Soil type data are also needed for estimating potential erosion and subsequent turbidity in streamflow. Information on depth of litter and nutrient status is needed for estimating nutrient release to streams.

6C3. WATER QUALITY

The present water quality of inflow streams including water temperature, turbidity, nutrients, such as nitrate, phosphate and calcium, total coliform bacteria and color is needed. Estimates of the same parameters for the modification and post-modification periods are necessary. Data on the same parameters are needed for the reservoirs and the Ware River downstream from Shaft 8.

6C4. OTHER INFORMATION

Research results from watershed experiments are needed for making projections of water quality changes. For setting the vegetation modifications, data on management objectives and any conflicting resource uses are necessary. Hydrologic data on evaporation and on streamflows are necessary for projecting water quality changes.

6D. EXISTING INFORMATION

6D1. VEGETATION

Forest type mapping has been completed in the spring of 1979 on MDC lands in Quabbin Reservoir watershed except for the islands in the reservoir. (Personal Communication, MDC, 3/12/80). Less precise type mapping based on 1951 and on 1971 aerial photographs is available for all the study areas including non-MDC lands (Noyes, 1967; Personal Communication, SCS, 5/1/80).

Continuous forest inventory (CFI) plot data for MDC lands in the Ware River Watershed is currently being processed and should be available soon. There is no current detailed forest type map available for the MDC Ware River watershed lands (Personal Communication, MDC 3/12/80).

6D2. SOILS

Soil type maps are available for the portion of Quabbin Reservoir watershed which is in Franklin County: Prescott Peninsula and the northwest section (Fuller and Mott, 1967). None of the rest of the watershed except scattered farms has been soil mapped (Personal Communication, SCS, 5/1/80).

Only small portions of the Ware River Watershed in Westminster and Rutland have been soil mapped. Soil maps are available for almost all of the Wachusett Reservoir watershed (Personal Communication, SCS, 5/1/80).

6D3. WATER QUALITY

Water quality data are available for streams flowing into Quabbin and Wachusett Reservoirs and for the Ware River (NER, 1972a, 1972b, 1973; U.S. EPA STORET, 1980).

Extensive data are available on Quabbin and Wachusett Reservoirs water quality from past studies by New England Research,Inc. (NER 1972a, 1972b, 1973, 1974, 1975, 1976, 1977, 1978, 1980), and from ongoing testing by the MDC.

6D4. OTHER INFORMATION

Extensive results of research on water yield from other geographic locations are available in the published literature. For example, Hibbert (1967), Swank and Miner (1968) and Lull and Reinhart (1967) indicate some of these results. Specific research on Quabbin Reservoir watershed has been done by Mrazik (1974) and Pywell (1977). Mrazik reported the results of a paired watershed experiment involving vegetation modification and Pywell reported on a multiple regression analysis of water yield changes. Streamflow data for Caldwell Creek and for the east branch of the Swift River are available (U.S.G.S., 1976).

E. EVALUATION OF INFORMATION

6E1. VEGETATION

The most recent vegetation type mapping (from 1971 aerial photos) is probably sufficient for planning vegetation management and for estimating effects of modifications, if it is supplemented to pick up changes since 1971. A major gap is development of the vegetation modification program - the types and location of vegetation to be modified, the methods to be used and the resulting vegetation.

6E2. SOILS

The soils data base is limited in areal coverage on the Quabbin and on the Ware River Watersheds, and therefore is not adequate for evaluating water quality impacts of an extensive vegetation modification program. The Wachusett watershed soils data is adequate except for data on MDC lands in Boylston.

6E3. WATER QUALITY

Water quality data are inadequate for evaluating the impacts of this alternative.

6E4. OTHER INFORMATION

The available information on watershed research results and hydrologic data is adequate for assessing impacts.

6F. RECOMMENDED APPROACH

6F1. VEGETATION

The recommended approach to update the 1971 vegetation mapping is threefold:

- Utilize any recent available aerial photographs to pinpoint new developments and clearings (e.g., from the Massachusetts Department of Public Works (MDPW).
- Use MDC timber sale records for changes on MDC land.
- Do a field reconnaissance check of areas not covered by the above two methods.

6F2. SOILS

The recommended approach to supplement available soils data is to have a reconnaissance-type survey done by the Soil Conservation Service on lands included in a vegetation modification program.

6F3. WATER QUALITY

A limited water quality sampling program, primarily for water temperature in inflowing streams will be the recommended approach to supplement available data.

7A. INTRODUCTION

The Upper Sudbury Watershed Alternative involves the increased utilization of the Sudbury Reservoir as a water supply for the MDC system.

The Upper Sudbury Watershed has continuously served the Metropolitan Boston area as a drinking water supply, and an emergency backup water supply since 1872. Major events in the history of the seventy-five square mile Upper Sudbury Watershed are as follows (CE Maguire, Inc., 1979):

- 1872 Sudbury River Act was passed allowing limited diversion of the Sudbury River
- 1875 Construction of the Sudbury Aqueduct and Framingham Reservoirs Nos. 1, 2 and 3 was begun
- 1889 Construction of Sudbury Reservoir
- 1896 Sudbury Reservoir complete
- 1912 Use of the south branch of the Upper Sudbury Watershed discontinued because of water quality
- Sudbury Reservoir and Reservoir #3 were continued in full use
- 1946 Quabbin Reservoir filled, reducing use of the lower quality Sudbury water
- 1947 Transfer of various Upper Sudbury River Reservoirs to recreational uses
- 1966 - 1978 Sudbury Reservoir and Reservoir #3 only utilized for emergency backup water supply.

The Commonwealth of Massachusetts Metropolitan District Commission has contracted with Parsons , Brinckerhoff, Quade and Douglas, Inc., to do a separate environmental impact study for the Sudbury Reservoir Treatment Plant. Their study will be the main assessment for the Upper Sudbury Watershed Alternative. The results of their study will be summarized and included in the Northfield study so that complete assessments of all alternatives appear in the Northfield EIR.

7B. MAJOR ISSUES

There are three major issues within the Upper Sudbury Watershed Alternative.

- Water quality with respect to public health is a paramount issue. If the waters of the Sudbury Reservoir are to be utilized as a supplementary water supply for the MDC system, they must meet the Federal and State drinking water quality standards (see Appendix 11A).

- The effects of this alternative upon the water quality of the Sudbury Reservoir.

- The effects of this alternative upon the water quality in downstream areas of the Sudbury and Concord Rivers.

7C. NECESSARY INFORMATION

In order to accurately assess the Upper Sudbury Watershed, it will be necessary to have the following data:

- Baseline information on the Sudbury Reservoir and downstream areas of the Sudbury and Concord Rivers.

- Water quality data on the Upper Sudbury Watershed with respect to the Federal and State standards (see Appendix 11A).

- Engineering data on the operation and condition of the Upper Sudbury Watershed system as an MDC water supply.

- Data on reservoir level and river stage fluctuations.

7D. EXISTING INFORMATION

There are a considerable number of reports, letters, brochures, and maps which provide baseline information on the history, development and condition of the Upper Sudbury Watershed, and the Sudbury Reservoir, and downstream areas of the Sudbury and Concord Rivers (McCann et al., 1972a, 1972c; Metcalf and Eddy,Inc., 1973; MDC,197 1976; Metropolitan Area Planning Council (MAPC), 1976; CE Maguire, Inc., 1979; and Coffin and Richardson, Inc. 1980).

Information on water quality for the Upper Sudbury Watershed is available for a number of years, from a variety of sources (McCann et al., 1972a, 1972c) which present water quality information on the Sudbury Reservoir with respect to such parameters as depth, color, drinking water classification, limnological classification, and stratification. Water quality data for thirty-five different physical and chemical parameters are available for the Sudbury Reservoir in CE Maguire, Inc., 1979. Water quality data for forty-two sites along the Sudbury and Concord Rivers and their tributaries, and for the Sudbury Reservoir are available through the STORET system of Region I EPA in Boston, Massachusetts (Personal Communication, U.S. EPA, 4/29/80). The STORET system does not contain a uniform amount of water quality information for each of the forty-two sites. Data are available on over twenty-five different water quality parameters at selected sites (U.S. Environmental Protection Agency STORET, 1980). A Coffin and Richardson, Inc.,1980 report includes water quality information on the Upper Sudbury River Supply with respect to 25 parameters, identifies pollution sources on the Upper Sudbury

Watershed, and identifies those parameters requiring treatment if this supply is to be utilized for drinking water. The U.S. Geological Survey report, Water Resources Data for Massachusetts and Rhode Island, Water Year 1975, also contains pertinent water quality information. In addition, Wilen (1976) reviews data for the Sudbury Reservoir and the Concord River on the parameter of organic color.

Information on the operation and condition of the Upper Sudbury Watershed system as an MDC water supply can be found in CE Maguire, Inc. (1979), Metcalf and Eddy, Inc. (1973), and MDC (1976).

Data are available on fluctuations in the Sudbury Reservoir surface level (Personal Communication, MDC, 5/1/80 and U.S. Geological Survey, 1976). In addition, there are data available on river stage fluctuations for the Sudbury and Concord Rivers (Personal Communication, U.S.G.S., 5/22/80; and U.S.G.S., 1976).

In addition, there is information on a water treatment facility proposal for the Sudbury Reservoir available in the literature (CE Maguire, Inc., 1979; and Coffin and Richardson, 1980).

7E. EVALUATION OF INFORMATION

A preliminary analysis of the existing information indicates that there are sufficient baseline and engineering data available so that additional studies should not be necessary.

The existing water quality information for the Upper Sudbury Watershed is inconsistent with respect to the parameters analyzed, the numbers and locations of sampling sites, and the time (season/year) in which the water quality studies were conducted. There are substantial water quality data for the Sudbury Reservoirs. Water quality data on the Sudbury Reservoir have been maintained for nearly one hundred years. In addition, the literature indicates that in recent years water quality studies have been conducted with respect to Public Law 93-523, the Safe Drinking Water Act (C.E. Maguire, Inc., 1979). Water quality data listed in this memo for the downstream areas of the Sudbury and Concord Rivers are intermittent and most of the water quality studies were conducted in the mid 1960's and early 1970's (U.S. EPA, STORET, 1980) Additional data on the Sudbury and Concord Rivers available from local sources, e.g., conservation commissions, may be available and sufficient.

7F. RECOMMENDED APPROACH

The evaluation of the existing information indicates that there are adequate data to determine the water quality and public health effects of the Upper Sudbury Watershed alternative.

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* More recent information is being reviewed by other MDC consultants.

However, additional data on the water quality of the downstream reaches of the Sudbury River and the Concord River other than those listed will be needed. This data may exist but it was beyond the scope of this phase of the study.

A separate EIR is being prepared for the Sudbury Reservoir Treatment Plant. Both the engineering and the environmental data will be reviewed in that project. Consequently no additional field studies are recommended under the Northfield EIR study for this alternative. It is recommended that the data and conclusions from the Sudbury EIR study be used to describe this alternative within the context of the Northfield EIR. This approach will avoid needless duplication of effort.

8A. INTRODUCTION

This alternative includes the potential use of abandoned and reserve water supplies in eastern Massachusetts.

One potential source of supply entails the reactivation of abandoned ground- and surface water supplies within the communities of the Metropolitan Water District (MWD). An engineering report on these supplies has been prepared recently for the U.S. Army Corps of Engineers (Coffin and Richardson, Inc., 1980), see Table 8-1.

Other potential sources of water supply include surface waters in eastern Massachusetts not in the MWD.

8B. MAJOR ISSUES

One major issue concerns the public health implications of utilizing abandoned water sources in the MWD that may be of relatively low quality due to domestic and industrial contamination, highway salting, large microbial numbers present and high color production. This issue applies to the use of other surface water supplies not in the MWD as well.

Another issue concerns the effects of high volume groundwater withdrawal on the ability of the groundwater source to tolerate the intrusion of saltwater or industrial and domestic contaminants. Subsequent reduction in water quality could result. In addition, the water levels of important nearby surface waters may be affected by groundwater withdrawal to the point that these surface sources may not be able to assimilate effluent discharges, thus affecting water quality.

8C. NECESSARY INFORMATION

Recent data of a wide variety of water quality parameters are needed for each supply considered in this alternative. Those parameters regulated by state and federal standards for drinking water serve as a basis for determining what data need to be obtained (see Appendix 11A). The issue concerning high volume groundwater withdrawal requires both hydrological data and engineering data for each of the groundwater supplies considered. Specifically, measurements of present groundwater levels and adjacent surface water level fluctuations and durations are needed. Chloride data concerning possible salt water intrusion and consequential effect on groundwater quality are needed, as well.

8D. EXISTING INFORMATION

Much of the existing information on water quality which is useful for evaluating this alternative is available from a report by Coffin and Richardson, Inc. (1980). This report provides a data base of a variety of water quality parameters for abandoned or reserve water supplies in Massachusetts. Appendix 11B summarizes the water quality data available in the Coffin and Richardson, Inc. report for nine selected sources.

Table 8-1. Nine Abandoned Water Sources in Eastern Massachusetts Identified as Potential Drinking Water Supplies by Coffin and Richardson, Inc. (1980) for U.S. Army Corps of Engineers.

- Charles River Wells
- Chicopee River Canal
- Cooley Brook and Morton Brook Reservoirs
- Dedham Avenue Supply
- Buckmaster Pond
- Lake Cochituate Wells
- Newton Water Works Reservation
- Rosemary Brook Supply
- Upper Sudbury River Supply

Baseline water quality data are available for both the surface and groundwater sources of Massachusetts (U.S.G.S., 1976). These data include the following:

- chemical data
  - concentrations of solutes
  - hardness
  - specific conductance
  - pH
  - radioactivity
- biological data (qualitative and quantitative analyses)
  - phytoplankton
  - periphyton
- microbiological data (quantitative identification)
  - bacteriological indicator organisms
- water temperature data
  - minimum
  - maximum
  - mean
- fluvial-sediment data
  - suspended-sediment concentrations and discharges

Limited water quality data are available in another publication for some Massachusetts' surface water sources (Wilen, 1976). Both color and turbidity were monitored and average values reported for the years 1965-1974.

Physical, biological, and land-use information on surface waters in Essex, Plymouth, Middlesex, Bristol, Worcester, Norfolk and Suffolk counties is available in a series of six publications (McCann, et al., 1972a, 1972b, 1972c, 1972d, 1972e and 1972f). These data include the following:

- surface area in acres
- altitude above sea level in feet
- mean and maximum depth in feet
- whether thermally stratified or not
- limnological classification
  - eutrophic (highly productive, aged)
  - mesotrophic (moderately productive, usually thermally stratified)
  - oligotrophic (of low productivity, thermally stratified)
  - bog (a boggy shore of low productivity)
  - brackish (tidal)
- transparency
- color
  - clear
  - brown (usually from tannic acid)
  - green (usually from suspended acid)
  - yellow (usually from suspended inorganic materials)

- subjective evaluation of degree of pollution (light, moderate, or heavy) for each type of pollution:
  - chemical
  - organic
  - siltation (suspended inorganic material)
  - thermal (heated water)
- subjective evaluation of degree of body use on a seasonal basis (light, moderate, heavy, exclusive) for each use:
  - drinking water
  - farming
  - industrial
- percent of shoreline being either used or developed for future use for each category:
  - residential
  - farmland
  - industrial
- distance from town

Available engineering data include yield estimates for abandoned or reserve surface waters of Massachusetts (Coffin and Richardson, Inc., 1980). These yield estimates are either the most recent ones available or are derived using generalized watershed yield curves. Also, maps are available illustrating such engineering data as generalized ground- and surface water potential for Massachusetts, source location of ground- and surface water supplies, and intertown and interbasin transfer (WFEM, 1978).

Additional water resource information is available for Massachusetts' ground- and surface water sources including stream discharge measurements, surface areas and contents of lakes and reservoirs, and water levels for wells in a series of annual reports (e.g., U.S.G.S., 1976).

8E. EVALUATION OF INFORMATION

Existing ground and surface water sources in eastern Massachusetts have been identified as potential drinking water supplies. However, no specific water sources have been identified as being feasible with respect to engineering considerations. More complete information is required regarding the specific potential of existing water sources before this alternative can be accurately evaluated.

One of the most recent water quality information sources available for potential eastern Massachusetts' surface water supply sources is Coffin and Richardson, Inc., (1980). Water quality parameter values are reported for each supply based on an average. It is difficult to determine the significance of these data values because no information is available regarding sampling frequency or number of sampling sites. For the same reason it is difficult to determine the significance

of the average color and turbidity values provided in the Wilen report (1976). In both of these publications, the years cited for chemical analyses indicate that the water quality data are not up to date. For example, analyses dates provided in the Coffin and Richardson report range from 1949 to 1978 for the top nine potential surface water supplies. In the Wilen report, analysis dates are 1965-1974. It appears, then, that the water quality data provided by these two publications may not be adequate for impact assessment due to a lack of information regarding sampling methodology and due to the fact that the data are not up to date.

Conversely, in the U.S.G.S. Water Resources Division report (1976), sampling methodology are described. Water quality data for ground and surface water sources were collected at hourly, daily, weekly, or monthly intervals. Descriptive statements are given of the designated surface water sampling sites, including location, drainage area, periods for water quality records, and data extremes. For groundwater sites, only well number, depth and sampling data are given. Because information is available regarding the sampling methodology employed, the significance of the data values reported can be determined. For this reason, the U.S.G.S. Water Resources Division Report (1976) is a pertinent one for evaluating this alternative. However, the data provided is not up to date.

The water quality information available in the six McCann et al., publications (1972a, 1972b, 1972c, 1972d, 1972e, and 1972f) is also not up to date. Several of the evaluations (e.g., degrees of pollution, degree of water body use, etc.) provided by this report are subjective and are reported using a scale of three (light, moderate, heavy).

While some recent information on groundwater quality is available (Coffin and Richardson, Inc., 1980; U.S.G.S., 1976), many gaps still exist. For example, recent information regarding chloride in potential groundwater sources is not available.

Estimates of yield for Massachusetts' abandoned or reserve surface water supplies are provided by Coffin and Richardson, Inc., (1980) but the data are not up to date. Water resource information provided by U.S.G.S. Water Resources Division (1976) contains recent engineering data for surface and groundwater sources in Massachusetts, including water level fluctuations and durations. These data are useful in assessing impacts of high volume groundwater withdrawal.

Generalized ground- and surface water potentials for all of Massachusetts are provided by WFEM (1972), however, the data are not up to date.

8F. RECOMMENDED APPROACH

The recommended approach for this alternative includes three actions:

1. The first recommendation is to conduct water quality surveys of those groundwater and surface sources within the MWD which have been identified as feasible supplies from the engineering perspective, and for which recent data are not available.

2. Another recommended action is to identify additional surface waters in eastern Massachusetts outside the MWD. These should be specific water supplies which are feasible from the engineering perspective.

3. Finally, when these other water supplies are identified, a water quality survey program should be undertaken. The water quality survey program should coordinate the studies of all supplies, whether inside or outside the MWD. This survey program should be based on the drinking water parameters summarized in Appendix 11A. This approach will provide a uniformity in the water quality data base for comparison with the standards.

9A. INTRODUCTION

This alternative includes the potential use of groundwater sources in eastern Massachusetts not considered in the previous alternative. These other sources include the groundwater aquifers in Plymouth County (WFEM, 1978).

9B. MAJOR ISSUES

One major issue concerns the public health implications of utilizing undeveloped groundwater sources that may be of relatively low quality due to high concentrations of naturally occurring soil minerals and organics. Also, these groundwater sources may be of low quality due to domestic and industrial contamination and highway salting.

Another issue concerns the effects of high volume groundwater withdrawal on the ability of the groundwater source to tolerate the intrusion of saltwater or industrial and domestic contaminants. Subsequent reduction in water quality could result. In addition, the water levels of important nearby surface waters may be affected by groundwater withdrawal to the point that these surface sources may not be able to assimilate effluent discharges, thus affecting water quality.

9C. NECESSARY INFORMATION

Recent data of a wide variety of water quality parameters are needed for each supply considered in this alternative. Those parameters regulated by state and federal standards for drinking water serve as a basis for what data need to be obtained (see Appendix 11A). The issue concerning high volume groundwater withdrawal requires both hydrological data and engineering data for each of the groundwater supplies considered. Specifically, measurements of present groundwater levels and adjacent surface water level fluctuations and durations are needed. Chloride data concerning possible salt water intrusion and consequential effect on groundwater quality are needed, as well.

9D. EXISTING INFORMATION

Baseline water quality data useful for evaluating this alternative are available for groundwater sources of Massachusetts (U.S.G.S., 1976). This data includes the following:

- chemical data
  - concentrations of solutes
  - hardness
  - specific conductance
  - pH
  - radioactivity
- biological data (qualitative and quantitative analyses)
  - phytoplankton
  - periphyton
- microbiological data (quantitative identification)
  - bacteriological indicator organisms
- water temperature data
  - minimum
  - maximum
  - mean

- fluvial-sediment data
  suspended-sediment concentrations and discharges

Information on groundwater quality is also available in a publication regarding chemical contamination of Massachusetts drinking water wells (Massachusetts Special Legislative Commission on Water Supply, 1979). Available information includes identification of the contaminant and description of the impact of the contamination event on the affected groundwater supply. In addition, alternatives for treatment of the contaminated groundwater supplies are discussed.

Groundwater resource information is available for various sections of Plymouth County in four Hydrologic Investigations Atlases (Williams, 1968; Williams and Tasker, 1974a, 1974b, 1977). Specifically, these sections are the Ten Mile and Taunton River basins, Weir River to Jones River basins, Plymouth River to Weweantic River basins, and the northwest shore basin of Buzzard's Bay.

Engineering data on water levels of groundwater sources are available for all of Massachusetts (U.S.G.S., 1976). In addition, maps are available illustrating such engineering data as generalized groundwater potential for Massachusetts, source location, and intertown transfer (WFEM, 1978).

9E. EVALUATION OF INFORMATION

Existing groundwater sources in eastern Massachusetts have been identified as potential drinking water supplies. However, no specific water sources have been identified as being feasible with respect to engineering considerations. More complete information is required regarding the specific potential of existing water sources before this alternative can be accurately evaluated.

While some recent information on groundwater quality is available (Massachusetts Special Legislative Commission on Water Supply, 1979; U.S.G.S., 1976) many gaps still exist. For example, recent information regarding chloride in potential groundwater sources is not available.

Water resource information provided by U.S.G.S. (1976) contains recent engineering data for groundwater sources in Massachusetts, and provides information concerning water level fluctuations and durations. These data are useful in assessing impacts of high volume groundwater withdrawal.

Generalized groundwater potentials for all of Massachusetts are provided by WFEM (1978). This report provides needed information on the Plymouth County aquifers. Additional Plymouth County groundwater resource information is provided by the four U.S.G.S. Hydrologic Investigations Atlases (Williams, 1968; Williams and

Tasker, 1974a, 1974b, 1977). However, the data are up to date.

9F. RECOMMENDED APPROACH

The recommended approach for this alternative includes the following actions:

1. Identify specific groundwater resources in eastern Massachusetts not considered in the previous alternative (Abandoned and Reserve Sources) that are feasible from an engineering perspective. These feasible water supplies could be used to augment the MWD system.

2. When these groundwater sources are identified, a water quality survey program should be undertaken based on the drinking water parameters summarized in Appendix 11A. This approach will provide a uniformity in the water quality data base for comparison with the standards.

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11A. WATER QUALITY

11A1. INTRODUCTION

This appendix summarizes water quality standards for drinking water. Standards legislated by the Federal Government and by the State of Massachusetts are included.

11A2. NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

Federal legislation, under the Safe Drinking Water Act of 1974, has specified all parameters to be monitored in public drinking water supplies (Table 1) in the National Interim Primary Drinking Water Regulations (U.S. EPA, 1975). Noted are requirements for these parameters to be monitored for non-community water systems as well as for community water systems (a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents).

11A3. NATIONAL SECONDARY DRINKING WATER REGULATIONS

National Secondary Drinking Water Regulations have specified secondary maximum contaminant levels for aesthetic parameters (Table 2). These secondary parameters are guidelines for states to follow, representing reasonable water quality goals, but are not federally enforceable. These regulations will be effective in 1981 (U.S. EPA, 1979b).

11A4. DRINKING WATER REGULATIONS FOR MASSACHUSETTS (1977)

The Massachusetts Department of Environmental Quality Engineering (DEQE) has promulgated maximum contaminant levels and monitoring requirements for specified parameters (Table 3) detailing applicability to community or non-community drinking water systems.

11A5. MASSACHUSETTS WATER QUALITY STANDARDS (1978)

Water Use Classification

The state rules and regulations follow guidelines set by the amended Federal Water Pollution Control Act. The Clean Water Act of 1977 recommends (1) designation of "use" for a water body, and (2) establishment of concentration limits of pollutants to maintain the designated use (U.S. EPA, 1979a, 1979b).

Class A Standards

The Massachusetts Water Quality Standards of 1978 include classification of bodies of water and designated uses. Class "A" waters are designated for use as a source of

public water supply. Parameters for all state waters and parameters for inland waters are included in Table 4.

11A6. TOXIC POLLUTANTS

The Federal Clean Water Act of 1977 requires publication of pollutants considered toxic with the most recent toxicological data of the effects of these pollutants on public health and welfare. Six of these pollutants are now being considered for inclusion into the Drinking Water Quality standards before the end of 1980 (Personal Communication, U.S. EPA, 5/21/80), on the basis of frequency of concern. Table 5 lists the parameters and identifies the status of information available at present (U.S. EPA, 1978b, 1979a, 1979c, and 1979d).

Toxicological data is based on health assessment of total exposure to a substance through different routes (i.e., ingestion, inhalation, dermal contact). Criteria determinations were made based on synergistic (co-operative) and antagonistic action of the substances, and on carcinogenic (tumor-producing), mutagenic (genetic-altering), and teratogenic (embryonic malformation-inducing) properties of these substances (U.S. EPA, 1979a).

11A7. RECOMMENDATIONS OF THE NATIONAL ACADEMY OF SCIENCES (NAS) (U.S. EPA, 1977)

The Safe Drinking Water Act calls for a study to be made by the NAS on human health effects of exposure to contaminants in drinking water. The NAS has provided a list of over one hundred contaminants, some duplicating the toxic pollutants list (U.S. EPA, 1979d), for which maximum contaminant levels should be determined (U.S. EPA, 1977). An assessment is in progress as to the risk of these substances to human health. NAS recommendations for study include bacteriological, viral and parasitic investigation, effects of solid particles in suspension, inorganic solutes, and organic solutes.

11A8. RADIOACTIVITY

State and federal regulations dealing with naturally-occurring radionuclides allow for screening of community water supplies for gross alpha particle activity. When in excess of the maximum contaminant level, the water supply must be tested for radium-226 and/or radium-228, depending on the concentration of gross alpha particle activity. Maximum contaminant levels for man-made radionuclides have been established on the basis of annual dose equivalents to the total body or to internal organs. Screening levels are established for beta particle and photon radioactivity. When maximum levels are exceeded the water supply must be analyzed to identify major radioactive constituents (U.S. EPA, 1976b and Drinking Water Regulations of Massachusetts, 1977).

Table 1. National Interim Primary Drinking Water Standards (U.S. EPA, 1975).

Parameter	Community Water Systems	Non-community Water Systems
Inorganic Chemicals:		
Arsenic	X	
Barium	X	
Cadmium	X	
Chromium	X	
Lead	X	
Mercury	X	
Nitrate Nitrogen	X	X
Selenium	X	
Silver	X	
Fluoride*	X	
Organic Chemicals:		
Chlorinated Hydrocarbons:		
Endrin	X	
Lindane	X	
Methoxychlor	X	
Toxaphene	X	
Chlorophenoxys:		
2,4-D	X	
2,4,5-TP Silvex	X	
Turbidity	X	X
Total Coliform Bacteria	X	X
Radionuclides	X	
Trihalomethanes	X (Serving 10,000 and more)	

* Maximum contaminant levels for fluorides depend on daily air temperature.

Table 2. National Secondary Drinking Water Regulations (Final Rule; U.S. EPA, 1979b)

Parameters:

- Chloride
- Color
- Copper
- Corrosivity
- Foaming Agents
- Iron
- Manganese
- Odor
- pH
- Sulfate
- Total Dissolved Solids
- Zinc

Table 3. Drinking Water Regulations of Massachusetts (1977)

Contaminant (Parameter)	Community Water Systems Utilizing Surface Water	Community Water Systems Utilizing Only Groundwater	All Non-Community Water Systems
Total Coliform Bacteria	X	X	X
Nitrate Nitrogen	X	X	X
Arsenic	X	X	
Barium	X	X	
Cadmium	X	X	
Chromium	X	X	
Lead	X	X	
Mercury	X	X	
Selenium	X	X	
Silver	X	X	
Fluoride*	X	X	
Sodium	X	X	X
Chlorinated Hydrocarbons:			
Endrin	X	Analysis by those systems specified by the DEQE	
Lindane	X		
Methoxychlor	X		
Toxaphene	X		
Chlorophenoxys:			
2,4-D	X		
2,4,5-TP Silvex	X		
Turbidity	X	X	X
Trihalomethanes			
Radionuclides	X	X	

*Maximum contaminant levels of fluoride depend on daily air temperatures

Table 4. Massachusetts Water Quality Standards (1978) for Class "A" Waters

Parameters applicable to all waters of the Commonwealth:

- Aesthetics
- Radioactive substances
- Tainting Substances
- Color, Turbidity, Total Suspended Solids
- Oil and Grease
- Nutrients
- Other Constituents

Parameters applicable to inland water classifications - Class "A" waters

- Dissolved Oxygen
- Temperature
- pH
- Total Coliform Bacteria
- Turbidity
- Total Dissolved Solids
- Chlorides
- Sulfates
- Nitrate

Table 5. Clean Water Act: Water Quality Criteria Availability for 65 Toxic Pollutants Human Health Criteria (U.S. EPA, 1978b, 1979a, 1979c, 1979d)

Pollutant	Status of Available Data
Acenaphthene	MCL
Acrolein	MCL
Acrylonitrile	ITRL
Aldrin/Dieldrin	ITRL
Antimony	MCL
Arsenic	ITRL
Asbestos	ITRL
Benzene	ITRL
Benzidine	ITRL
Beryllium	ITRL
Cadmium	MCL
Carbon Tetrachloride *	ITRL
Chlordane	MCL
Chlorinated benzines	MCL (HCB:ITRL)
Chlorinated ethanes *	MCL, ITRL, ID
Chloroalkylethers	MCL, ITRL
Chlorinated naphthalenes	MCL
Chlorinated phenols	MCL
Chloroform	ITRL
2-chlorophenol	MCL
Chromium	MCL (Cr^{+6}: ITRL)
Copper	MCL
Cyanide	MCL
DDT	ITRL
Dichlorobenzenes (Total)	MCL
Dichlorobenzidine	ITRL
Dichloroethylenes	ITRL
2,4-dichlorophenol	MCL
Dichloropropanes/propenes	MCL
2,4-diemthylphenol	ID
Dinitrotoluene	ITRL
Diphenylhydrazine	ITRL
Endosulfan	MCL
Endrin	MCL
Ethylbenzene	MCL
Fluoranthene	MCL
Haloethers	ID
Halomethanes	MCL
Heptachlor	ITRL
Hexachlorobutadiene	ITRL
Hexachlorocyclohexane	ITRL
Hexachlorocyclopentadiene	MCL
Isophorone	MCL
Lead	MCL
Mercury	MCL
Naphthalene	MCL
Nickel	MCL
Nitrobenzene	MCL
Nitrophenols	MCL (none for mono-)
Nitrosamines	ITRL
Pentachlorophenol	MCL
Phenol	MCL

Pollutant	Status of Available Data
Phthalate esters	MCL
Polychlorinated biphenyls (PCB's)	ITRL
Polynuclear aromatic hydrocarbons	ITRL
Selenium	MCL
Silver	MCL
2,3,7,8-tetrachloro-dibenzo-p-dioxin	ITRL
Tetrachlorethylene*	ITRL
Thallium	MCL
Toluene	MCL
Toxaphene	ITRL
Trichloroethylene *	ITRL
Vinyl chloride*	ITRL
Zinc	MCL

MCL: maximum contaminant levels available
ITRL: interim target risk levels being considered
ID: insufficient data

* Six pollutants being considered for addition in 1980 to drinking water regulations (includes two chlorinated ethanes)

11A9. MICROBIOLOGY

The only microbiological monitoring parameter mandated by federal and state legislation is for total coliform bacteria (U.S. EPA, 1975 and Drinking Water Regulations of Massachusetts, 1977). However, the National Academy of Sciences (NAS) recommends development of new microbiological standards for water reclaimed directly from wastewater (U.S. EPA, 1977). The total coliform bacteria test currently provides the most inexpensive and practical method for screening for biological contamination. Fecal coliform bacteria (Escherichia coli) are inadequate for screening because of their short survival time. Practical screening methods for virus contamination have not yet been developed. However, the total coliform screening is not an effective indicator of success of treatment methods because viruses can last longer and be more resistant to disinfection and other treatment processes than bacteria. Water-borne pathogens have been implicated directly in disease outbreaks, and indirectly by contamination of edible aquatic organisms. Pathogenic diseases caused by bacteria, viruses, amoebas, worms and fungi can be attributed to wastewater contamination of water used for drinking and for contact recreation. (U.S. EPA, 1976 and U.S. Army Corps of Engineers, 1975).

11A10. REFERENCES

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Metcalf and Eddy, Inc. October 1975. Wastewater Engineering and Management Plan for Boston Harbor - Eastern Massachusetts Metropolitan Area (EMMA Study), Vol. 13C, Hygienic Impact Analysis.

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United States Environmental Protection Agency (U.S. EPA). November 29, 1979e. National Interim Primary Drinking Water Regulations; Control of Trihalomethanes in Drinking Water; Final Rule. Federal Register, Vol. 44, No. 231, pp. 68624-68707.

United States Environmental Protection Agency (U.S. EPA). May 21, 1980. Personal Communication. Boston, Massachusetts.

11B. SELECTED SURFACE WATER SUPPLIES WITHIN MWD

This appendix summarizes the specific water quality parameters available for nine abandoned or reserve surface water supplies within the MWD (Coffin and Richardson, Inc., 1980).

Water Quality Parameters	Number of Potential Water Supplies with Data
pH	9
Total alkalinity	9
Hardness	8
Suspended solids	1
Turbidity	5
Total solids	1
Color	9
Ammonia nitrogen	5
Nitrate nitrogen	6
Total nitrogen	1
Dissolved oxygen	1
Dissolved oxygen at saturation	1
Phosphate	1
Total phosphorus	1
Free ammonia	1
Albuminoid ammonia	1
Chlorides	9
Sulfate	3
Oil and grease	1
Total residue	1
Residue loss at ignition	1
Fixed residue	1
Free carbonic acid	1
Specific conductivity	3
Iron	9
Lead	2
Zinc	2
Nickel	1
Silver	1
Copper	4
Chromium	2
Cadmium	2
Mercury	2
Aluminum	1
Arsenic	1
Fluoride	1
Manganese	6
Magnesium	3
Sodium	4
Potassium	3
Calcium	3
Silica	3
Nitrates	3
Nitrites	1
Sediment	1

11B1. REFERENCE

Coffin and Richardson, Inc., 1980. Abandoned or Reserve Water Supplies, Metropolitan District Commission Service Area. Boston, MA: Prepared for U.S. Army Corps of Engineers.

REPLIES TO COMMENTS
ON DRAFT TECHNICAL MEMORANDUM
WATER QUALITY - RESERVOIRS, SURFACE AND
GROUNDWATER SUPPLIES, NORTHFIELD EIR

COMMENTS BY NORTHFIELD CITIZENS ADVISORY COMMITTEE

Note: These questions are reproduced as received, except for minor editorial corrections. Page numbers refer to the draft memorandum pages.

QUESTION: (1) Page 2, Table 1.1. Under the "Quabbin Watershed Management" Alternative it should be pointed out that consideration will also be given to management of land along the Ware River at Wachusett Reservoir.

REPLY: Please see section on "Description of the Alternative". All three watersheds are included.

QUESTION: (2) Page 2, 3 and 4. The phrase "flood skimming" should be defined.

REPLY: Flood skimming is defined in the Engineering Technical Memorandum, Appendix

QUESTION: (3) Page 3, Table 1.2. In regard to the "Upper Sudbury Watershed" Alternative. How will efforts be coordinated with the Sudbury EIR project?

REPLY: The Parsons-Brinkerhoff EIR study will be the main assessment for the Sudbury alternative. The results of this study will be summarized and included in the Northfield EIR so that a complete assessment of all alternatives appears in the Northfield EIR.

QUESTION: (4) Page 3, Table 1.2. Under the "Conn. River Tributaries" Alternatives and the "Northfield Flood Skimming" Alternative, what is meant by a conceptual model?

REPLY: Please refer to the figure entitled "Conceptual Model of a Systems Approach to an Impact Assessment Process" and the "Recommended Approach" section of the Northfield Flood Skimming Alternative in the technical memorandum for a discussion of the conceptual model.

QUESTION: (5) Page 3, Table 1.2. Under the "Groundwater and Surface Water in Eastern Massachusetts" Alternative, how will supplies within the MWD be selected for water quality surveys?

REPLY: Water supplies within the MWD will first be screened for engineering feasibility. Only those supplies deemed feasible will be checked for existing water quality data and only those supplies without adequate data would be actually tested.

QUESTION: (6) Page 3, Table 1.2. Will consideration be given to water resources within the MWD as well as outside the MWD? Will consideration be given to potential sources primarily in eastern Mass?

REPLY: Yes. Yes.

QUESTION: (7) Page 3, Table 1.2. Can the same approach be used to evaluate each alternative?

REPLY: No. Approach, as used in Table 1.2, is the work to be done in Phase II to fill data gaps and make the environmental assessments. Each alternative has different issues and different gaps, and therefore different approaches will be used to fill those gaps.

QUESTION: (8) Page 9, Sudbury Alternative. Will the EIR address multiple use aspects or reservoirs (see attached comments from D.H. Stickel).

REPLY: The Sudbury EIR will presumably address multiple use aspects of the reservoir. The Northfield EIR will summarize the findings of the Sudbury EIR to put all alternatives in perspective.

QUESTION: (9) Page 11. Existing information. Are there more recent data available (more recent than 1972, 1973, or 1975) for the tributaries? Have the consultants seen any of the reports published by Dr. Edward Klekowski of the Botany Department at the University of Massachusetts in Amherst? It is noted that "extensive water quality data are available for Quabbin Reservoir." It could be helpful for the reader to know exactly when and where samples were taken, as well as what parameters were tested.

REPLY: For information on the tributaries refer to the Technical Memorandum of Water Quality - Rivers and Estuaries, Appendix . Dr. Klekowski has studied mutagenic materials in the Millers River system and his findings will be considered in Phase II. Citation of details on parameters, stations, and frequencies for each study was considered beyond the scope of work for the Phase I memoranda. In general, most parameters have been measured monthly at several stations in Quabbin Reservoir.

QUESTION: (10) Page 15, paragraph 3. Consideration should be given to fisheries populations as well as public health problems.

REPLY: Yes. See revised text.

QUESTION: (11) Page 15, paragraph 4. Which model will be used for the "modeling study outputs"?

REPLY: The phrase "modeling study outputs" refers to a proposed hydrodynamic model to be developed in Phase II of this project.

QUESTION: (12) Page 18. Table 5-1. The inclusion of the data the report was published along with the agency for whom the study was undertaken would be helpful. The Ellis Station Supply was reported to be excessively costly, but Buckmaster Pond was estimated to yield 1.5 mgd. A tabular presentation of the estimated yields of these sources is important for comparative purposes (see enclosed p. 18). On pages 63 and 64 consultants should remove Ellis Station and add Buckwater Pond.

REPLY: Corrections have been made accordingly. Please see revised text.

QUESTION: (13) Pages 19 and 23. Consideration should also be given to halogenated hydrocarbon contaminants.

REPLY: As suggested in the text, please refer to Appendix 10A. Tables 1 and 3 in this Appendix identify halogenated hydrocarbons as pertinent drinking water parameters useful for consideration of the public health issue.

QUESTION: (14) Page 24, 6A.2. Description of the Alternative. A clear and precise definition of what is meant by a "non-living cover" should be given (see attached comments from D.W. Stickel).

REPLY: Maximum water yield increases are achieved when evapotranspiration is minimized. Non-living surfaces such as talus slopes or boulder fields have minimum evapotranspiration rates. In Phase II a wide range of watershed management alternatives will be considered for realistic options. Please see revised text.

QUESTION: (15) Page 26, 6D. Existing Information. In citations of "personal communication" the name of the person contacted along with his or her position with an agency should be given.

REPLY: The adopted policy has been to include only the agency name and date when making reference to personal communications.

QUESTION: (16) Page 30, 7F. Recommended approach. NCAC assumes that one of the various "hydrologic scenarios" to be investigated will include the conservation efforts presently underway in MDC user communities (including efforts by the Boston Water and Sewer Commission.) .

REPLY: This will be considered under the Conservation Alternative in other technical memoranda.

QUESTION: (17) Page 31. What type of models will be used to do the projection? How realistic is it to use the 1960's drought --- is it a 100 year event?

REPLY: The mathematical hydrologic model used for safe yield estimates will be used to project future reservoir levels, based on the results of the demand projections. The 1960 drought data is part of the historical record that goes into the mathematical model.

QUESTION: (18) Page 32. A clear and precise definition of what is meant by "flood skimming" should be given. The way existing legislation is worded, diversion of water from the Conn. River at Northfield Mountain Pumped Storage Reservoir could be implemented during any month of the year (see attached report from the Federal Power Commission, Dec. 1976).

REPLY: The term "flood skimming" is defined by the engineering consultant; see Engineering Technical Memorandum, Appendix .

QUESTION: (19) Page 34, 8E. Evaluation of Information. How will water quality standards in the Northfield Pumped Storage Reservoir be maintained?

REPLY: This question is unclear. Water quality standards are set and maintained by the Massachusetts Division of Water Pollution Control.

QUESTION: (20) A general comment from S. Cole, former "208" Planner with LPVRPC, "The memo is (1) too general, (2) it does not appear that data and final results will be comparable among the alternatives, and (3) hopefully, in the next scope of Service the emphasis will be placed on eastern Massachusetts."

REPLY: The purpose of the technical memo was to address the findings, in terms of adequacy, of the data reviewed, as well as to raise issues for further consideration. The detailed analysis of these issues will be carried out in later phases as suggested by the recommended approach in the memo. For evaluation purposes, equal emphasis will be placed on all alternatives looked at for assessment of environmental impacts.

QUESTION: (21) Pages 36-50. References. Citations should follow a standard format which includes author's name, date of publication, title of document, and location of document.

REPLY: Please see revised References section.

QUESTION: (22) Page 59, 10A.9. Microbiology. How do the consultants propose to cope with the problem of adequate monitoring for water-borne pathogens?

REPLY: This problem will be studied as part of Phase II.

COMMENTS BY D.W. STICKEL

Note: These questions are reproduced as received, except for minor editorial corrections. Page numbers refer to the draft memorandum pages.

QUESTION: Page 9. As an added thought will the EIR address multiple use aspects of reservoirs? That is, can the Sudbury be used as both a drinking supply and for recreational purposes as is done in some midwestern reservoirs?

REPLY: The EIR will address multiple use aspects of reservoirs to the extent of the existing multiple uses of those reservoirs (e.g., drinking water supply, recreational fishing). Additional uses cannot be addressed in the water quality assessment, but will be considered where pertinent under the land use analysis for recreational uses of reservoirs.

QUESTION: Page 15. Again at the end of this paper there is a need to address not only public health issues but also fisheries populations as well.

REPLY: Yes. Please see revised text.

QUESTION: Page 19. Mention here is made of all sorts of classical parameters but no mention made of halogenated hydrocarbon contaminants. And again on page 23 no mention is made thereof.

REPLY: Tables 1 and 3 of Appendix 10A identify halogenated hydrocarbons as pertinent drinking water parameters useful for consideration of the public health issue.

QUESTION: Page 24. "Replacing the existing vegetation with a non-living cover". In my judgement discussion of this unrealistic alternative will turn the general public and public opinion away from this alternative because of the public's perception of actual consideration of this alternative.

REPLY: Please see revised text.

QUESTION: Page 26, and others as well. References to Personal Communication, MDC or SCS, etc. are not appropriate unless it is established policy. A better way would be to mention the individual specifically as this denotes better credibility.

REPLY: The adopted policy has been to include only the agency name and date when making reference to personal communications.

QUESTION: Page 31. I object to this whole discussion of No Action Alternative without reference to a conservation baseline which is taking place now. Projecting No Action Alternatives into the future without a concomittant conservation baseline (which we know will ascend) is unrealistic.

REPLY: See the Conservation Alternative in other technical memoranda.

QUESTION: Page 32. I seriously object to continued use of the words "Northfield Flood Skimming". It is obvious to the most ill informed that diversion at Northfield according to present legislation, can occur AT EVERY MONTH OF THE YEAR!! Please see the enclosed.

REPLY: The term "Northfield Flood Skimming" is defined by the engineering consultant in the Engineering Technical Memorandum Appendix

QUESTION: Finally, is any review of the Lower Sudbury to be undertaken? I also find the map references in this report and the other NAI report concerning the Upper Sudbury to be at variance with the maps of the Upper and Lower Sudbury River Supplies in Coffin & Richardson report (1980).

REPLY: The map has been deleted. The geographic scope of the Sudbury Alternative is being reviewed in the Sudbury EIR study. The results of the Sudbury EIR study will be summarized in the Northfield EIR, and thus the geographic scope should be standardized.

COMMENTS BY PERSONS AT MEETINGS

QUESTION: Must say whether water quality, ecology data is adequate.

REPLY: See revised text.

METTING ON 6/6/80

QUESTION: (By Stickel) Suggested rating the alternatives 1-10.

REPLY: This is not the function of the water quality assessment alone. Ratings would include many inputs which would be integrated in making a final evaluation and recommendation of a preferred alternative.

QUESTION: (By Hubley) Quabbin Watershed Management seems too categorical. Can we do something between clear cutting and doing nothing.

REPLY: The draft report gave a maximum value that could be expected from extreme management. Phase II will consider a wide range of watershed management scenarios between the extremes mentioned in the question.

QUESTION: Can the implications of less management be shown in terms of vegetation changes implied?

REPLY: The question is unclear. In general, varying levels of vegetation density will have varying impacts on water yield and on other resources such as wildlife.

QUESTION: Problem of contaminated water supplies. Impact of contaminants on groundwater sources.

REPLY: Contaminated water supplies are a continuing problem in Massachusetts. Decontaminating a surface supply can be done if the contaminant source is located and removed. Contaminated groundwater sources pose more difficult problems in locating sources of contamination and in decontaminating the supply because natural flushing is so slow in groundwater sources.

MEETING ON 6/19/80

QUESTION: (By Johnson) Re: pool fluctuations. Will there be any considerations of what wildlife there was before the pool was in effect?

REPLY: No. The objective of the EIR is to indicate the existing conditions and then project what the future conditions will be if the alternative is implemented. Retrograde projections are not a part of the EIR.

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TECHNICAL MEMORANDUM

TASK 1.4-4

ECOLOGY-

RESERVOIRS, SURFACE AND GROUNDWATER SUPPLIES

NORTHFIELD EIR

REPORT NO. NER-144-02

SUBMITTED TO

WALLACE, FLOYD, ELLENZWEIG, MOORE, INC.

JULY 11, 1980

Environmental Consulting Services

LIST OF FIGURES

New England Research, Inc. (NER) has conducted a Phase I study of the ecological issues associated with various alternatives included in the Northfield EIR Project. This section summarizes the major findings contained in the technical memorandum report on the Phase I study.

The general approach to the Phase I study included (1) defining major ecological issues associated with each alternative, (2) compiling the relevant data and information available, (3) assessing the adequacy of the data base available for addressing the issues, and (4) making recommendations for approaches for future, Phase II studies.

The major ecological issues encompass a wide range of potential impacts associated with the alternative actions. These include potential increases in eutrophication, potential effects on aquatic habitat, potential effects on the fisheries in reservoirs, potential effects on terrestrial wildlife, and the potential loss of habitat for rare and endangered species.

Table 1-1 provides a summary of the evaluation of the information required to evaluate the major ecological issues associated with each alternative. The table also summarizes the adequacy of the information necessary for the assessments in Phase II. All the evaluations summarized in the table relate to the major ecological issues.

The Phase I study also provided recommendations for approaches to subsequent efforts. Table 1-2 is a summary of the recommended approaches for future efforts.

Table 1-1. Summary of Evaluation of Information Required for Ecological Impact Assessment.

Alternative	Necessary Information	Adequacy Status Adequate	Inadequate
No Action	Data on the Flora and Fauna of the Aquatic and Terrestrial Communities of the Quabbin, Wachusett, and Sudbury Reservoirs		X
	Water Quality Data for the Reservoirs	X	
	Projected Data on Reservoir Levels and Fluctuations		X
Northfield Flood Skimming	Water Quality Data on Connecticut River		X
	Water Quality Data on Northfield Reservoir	X	
	Water Quality Data on Quabbin Reservoir	X	
	Fisheries Data on Connecticut River		X
	Fisheries Data on Northfield Reservoir	X	
	Fisheries Data on Quabbin Reservoir	X	
	Engineering Data on Flood Skimming		X
	Hydrodynamic Studies		X
	Toxicology Data for Fish Control		X
Connecticut Tributaries Flood Skimming	Water Quality Data on Tributaries		X
	Water Quality Data on Quabbin Reservoir	X	
	Fisheries Data on Tributaries		X
	Fisheries Data on Quabbin Reservoir	X	

Alternative	Necessary Information	Adequacy Status Adequate	Inadequate
Connecticut Tributaries Flood Skimming (Cont.)	Engineering Data on Flood Skimmings		X
	Hydrodynamic Studies		X
	Toxicology Data for Fish Control		X
Quabbin Watershed Management	Vegetation Modification Program		X
	Terrestrial Community Data on Quabbin, Wachusett and Ware River Watersheds		X
	Aquatic Community Data on Quabbin and Wachusett Reservoirs, the Ware River and Their Tributary Streams		X
	Data on Rare and Endangered Species		X
Upper Sudbury Watershed	Data on the Flora and Fauna of the Aquatic and Terrestrial Communities of the Sudbury Reservoir and the Sudbury and Concord Rivers		X*
	Water Quality Data on the Sudbury Peservoir	X	
	Water Quality Data on the Sudbury and Concord Rivers		X*
	Data on Reservoir Levels and River Stage Fluctuations	X	
Abandoned and Reserve Sources	Data on Flora and Fauna on Water Supplies and Adjacent Wetlands		X
	Engineering Data		X
Groundwater - Plymouth Aquifer	Location of Ecological Communities that May be Affected		X
	Data on Flora and Fauna of Above Communities		X
	Habitat Requirements of Flora and Fauna Affected (especially rare and endangered species)		X
	Engineering Data		X

* New information is being reviewed by other MDC consultants.

Table 1-2. Summary of Recommended Approaches for Future Efforts.

Alternative	Recommended Approaches for Future Efforts
No Action	Make predictions of future reservoir levels over several decades, including extended drought conditions. Estimate changes in water quality related to changes in reservoir levels. Evaluate impacts on warm- and cold-water fisheries. Conduct rare and endangered species survey. Evaluate impacts on adjacent terrestrial communities.
Northfield Flood Skimming	Acquire additional data on Connecticut River as needed. Apply conceptual model to impact assessment process. Consider several alternative approaches to assessing aquatic ecological impacts. Evaluate impact on fisheries. Conduct supplementary toxicological studies.
Connecticut Tributaries Flood Skimming	Acquire additional data on tributaries as needed. Apply conceptual model to impact assessment process. Consider several alternative approaches to assessing aquatic ecological impacts. Evaluate impact on fisheries. Conduct supplementary toxicological studies.
Quabbin Watershed Management	Develop a vegetation modification program. Conduct a reconnaissance soil survey. Conduct rare and endangered species survey. Conduct supplemental vegetation surveys. Conduct supplemental water quality measurements.
Upper Sudbury Watershed	Coordinate efforts with Sudbury EIR project.
Abandoned and Reserve Sources	Identify specific sources. Conduct engineering studies regarding surface level fluctuations and durations. Conduct ecological data surveys on aquatic and terrestrial communities that may be affected by this alternative.
Groundwater - Plymouth Aquifer	Identify specific sources. Conduct engineering studies regarding surface level fluctuations and durations. Conduct ecological data surveys on aquatic and terrestrial communities that may be affected by this alternative.

This is a technical memorandum which summarizes the findings of studies conducted by New England Research, Inc. (NER) during Phase I of the Northfield EIR Project.

NER is providing environmental consulting services to Wallace, Floyd, Ellenzweig, Moore, Inc. (WFEM), and is assessing the water quality and ecology of reservoirs and other, selected water resources included in the scope of the project. This is a technical memorandum on the ecological segment of the study. Both terrestrial and aquatic ecology are included in this report. A separate technical memorandum (NER-144-01) describes the water quality segment of the study.

Seven alternatives are included in this part of the study. These alternatives include the following:

- No Action
- Northfield Flood Skimming
- Connecticut Tributaries Flood Skimming*
- Quabbin Watershed Management
- Upper Sudbury Watershed
- Abandoned and Reserve Sources**
- Groundwater - Plymouth Aquifer**

Each alternative has been evaluated with a standard procedure. This procedure is based upon a series of five key questions:

1. What are the major environmental issues?
2. What is the necessary information to evaluate the issues?
3. What is the existing information available for evaluation?
4. Is the existing information adequate to evaluate the issues?
5. What is the approach recommended for future studies?

The organization of this technical memorandum reflects these key questions.

* In the Scope of Work, this alternative was named Connecticut River Tributaries.

** These two alternatives make up the alternative named in the Scope of Work as Groundwater and Surface Water in User Communities, Possible Future Communities, Metropolitan Boston, and Plymouth County.

3A. INTRODUCTION

The No Action Alternative is a key element in the assessment of the Northfield EIR. It provides a baseline condition against which the other alternatives may be assessed.

The No Action Alternative, which extends through the year 2020 (WFEM, 1979) has the potential to have direct and indirect impacts upon the parameters of the physical, biological, and social environments of the project area, and the interrelationships which exist between these environments. Conditions prevailing during this period will be estimated from supply and demand projections.

3B. MAJOR ISSUES

Under the No Action Alternative there are two major ecological issues:

- The effects changes in the water quantity and quality will have on the aquatic ecosystems of the Quabbin, Wachusett and Sudbury Reservoirs, due to the no action condition.
- The effects changes in the water quantity and quality will have on the terrestrial ecosystems adjacent to the Quabbin, Wachusett and Sudbury Reservoirs, due to this alternative.

3C. NECESSARY INFORMATION

In order to effectively evaluate the No Action Alternative it is necessary to have the following data:

- Baseline data on the aquatic communities of the Quabbin, Wachusett and Sudbury Reservoirs, with respect to flora and fauna.
- Baseline data on the terrestrial communities adjacent to the Quabbin, Wachusett and Sudbury Reservoirs, with respect to flora and fauna.
- Identification of rare and endangered species (if they exist) which may be found within the aquatic and terrestrial communities of the Quabbin, Wachusett and Sudbury Reservoirs and adjacent watersheds.
- Data on water level fluctuations within the Quabbin, Wachusett and Sudbury Reservoirs.
- Data on changes in water quality with respect to fluctuations in the Quabbin, Wachusett, and Sudbury Reservoirs' water levels due to the no action condition.

3D. EXISTING INFORMATION

There is a substantial amount of data available on the aquatic communities of the Quabbin, Wachusett and Sudbury Reservoirs with respect to fish, algae,

plankton and invertebrates (NER, 1972a, 1972b, 1973, 1974, 1975a, 1975b, 1976, 1978, and 1980; MDC, 1970; Massachusetts Division of Fisheries and Game, 1978; Rho et al., 1969; CE Maguire, Inc., 1979; McCann et al., 1972a, 1972c; Coffin and Richardson, Inc., 1980; and Bridges and Hambly, 1971).

Information on flora and fauna in terrestrial communities is variable with respect to the different reservoirs. Available data on these communities are discussed in the Quabbin Watershed Management and Upper Sudbury Watershed Alternatives.

Flora and fauna which have been classified in State and Federal regulations as rare and endangered species are identified in Appendix 11B. Data on rare and endangered plants in the Quabbin and Wachusett watersheds is extremely limited, and there is no record of recent rare plant surveys (Personal Communication, MNHP, 5/1/80). Recent data on rare and endangered animals on the Quabbin, Wachusett and Sudbury Watersheds is also limited. There is no record of recent surveys for rare animals on any of the three watersheds, (Personal Communication, MNHP, 5/1/80). However, the presence of wintering populations of bald eagles on Quabbin Reservoir has been documented on film (Personal Communication, Massachusetts Division of Fisheries and Wildlife, 5/22/80).

Data on water level fluctuations are available with respect to the different reservoirs. Information is available on changes in the reservoirs' surface elevations during the 1960's (drought period) and during the period of above normal precipitation in the 1970's (Personal Communication, MDC, 5/1/80). Pertinent literature on water level fluctuations for the Quabbin and Wachusett Reservoirs is as follows: Erickson et al., 1975; Miner, 1974; and Higgins, 1968.

There are a substantial amount of water quality data available for the Quabbin, Wachusett and Sudbury Reservoirs. Types of data on water quality which are available for these areas are discussed in the Technical Memorandum on Water Quality- Reservoirs, Surface and Groundwater Supplies (Report No. NER-144-01) under the alternatives: Northfield Flood Skimming, Quabbin Watershed Management and Upper Sudbury Watershed.

3E. EVALUATION OF INFORMATION

The existing information on the flora and fauna of the terrestrial and aquatic communities of the Quabbin, Wachusett and Sudbury Reservoirs and adjacent land areas is incomplete. A preliminary analysis of the existing information indicates that there are gaps in the quantitative data available for some of the components of the terrestrial and aquatic communities.

There is no record of recent surveys for rare and endangered plants and animals on the Quabbin, Wachusett and Sudbury Reservoirs (Personal Communication, MNHP, 5/1/80). Existing data on rare and endangered species consist of general descriptive evaluations, with little or no site specific information.

There are sufficient data available with respect to prior water level fluctuations and water quality at each of the reservoirs to estimate the effects of water level and water quality fluctuations on the terrestrial and aquatic communities of the reservoir areas.

3F. RECOMMENDED APPROACH

The evaluation of existing information indicates that there are inadequate data to assess the impacts of the No Action Alternative on the terrestrial and aquatic communities of the Quabbin, Wachusett and Sudbury Reservoirs and adjacent areas.

The recommended approach for the Sudbury Reservoir is covered in detail in Section 7F, Recommended Approach Upper Sudbury Watershed.

Field studies to identify the terrestrial flora and fauna (particularly with respect to rare and endangered species) of the Quabbin and Wachusett Reservoir areas are necessary.

It will be necessary to make predictions of future water levels in the MDC reservoirs under a variety of hydrologi scenarios. Therefore it is recommended that future water levels for Quabbin Reservoir, Wachusett Reservoir and Sudbury Reservoir be projected under a series of hydrologic conditions through the year 2020.

The projected changes in water levels will be used to estimate changes in water quality and impacts on warm- and cold-water fisheries and other components of the aquatic communities. The projected changes will also be used to estimate impacts on terrestrial communities adjacent to the reservoirs.

4A. INTRODUCTION

One of the alternatives for augmenting the water supply of the MDC system involves skimming water from the Connecticut River via the Northfield Reservoir during periods of high water flow; (flow exceeding 17,000 cfs in the Connecticut River).

This alternative was included in the NEWS Study of the U.S. Army Corps of Engineers and the MDC (NER, 1972a; U.S. ACE, 1973; Erickson et al., 1975). Since this study, the Northfield pumped storage hydroelectric facility operated by Northeast Utilities has become operational. Northfield Reservoir is a pumped storage reservoir for this hydroelectric facility.

Over the past decade the Northfield Flood Skimming Alternative has been studied by several groups, including the New England River Basins Commission (NERBC, 1972), the Federal Power Commission (now Federal Energy Regulatory Commission, 1976) and the Commonwealth of Massachusetts (WFEM, 1978, 1979).

4B. MAJOR ISSUES

The major ecological issues associated with this alternative include the possible introduction of excessive nutrients (e.g., nitrogen, phosphorus) and other constituents into Quabbin Reservoir. This could lead to potential increases in the eutrophication (nutrient-enrichment and aging process) rates in the reservoirs.

Another major ecological issue is the possible introduction of undesirable fish species into Quabbin Reservoir and possibly into Wachusett Reservoir. Both reservoirs currently have balanced and highly prized fisheries, including salmonids (trout, salmon). Introduction of undesirable species such as the carp and the lamprey could change the ecological balance of the reservoirs.

4C. NECESSARY INFORMATION

The data necessary to evaluate the ecological issues associated with this alternative include the following:

1. Water quality data for the Connecticut River.
2. Water quality data for Northfield Reservoir.
3. Water quality data for Quabbin Reservoir.
4. Fisheries data for the Connecticut River.
5. Fisheries data for Northfield Reservoir.
6. Fisheries data for Quabbin Reservoir.
7. Engineering data on the proposed skimming.
8. Hydrodynamic data on the proposed skimming.
9. Toxicology data for selected fish species.

Water quality data which are relevant to aquatic ecology and aquatic habitat include the following parameters:

- dissolved oxygen
- temperature

- pH
- turbidity
- dissolved solids
- nitrogen parameters
- phosphorus parameters

Additional details on water quality parameters in relation to aquatic ecology and aquatic habitat are shown in Appendix 11A.

Fisheries data required for this assessment include the following:

- density (relative numbers)
- diversity (types of species)
- spawning data and information
- creel census data

The water quality data and the fisheries data should include data from the Connecticut River, Northfield Reservoir and Quabbin Reservoir.

Engineering data on the proposed skimming operations will also be required. Details should include:

- amounts of water skimmed
- where the water would enter the reservoir
- the time of the year
- typical flood skimming cycles
- hydraulic data on the transit through the aqueduct

Hydrodynamic data will be needed to provide information on the mixing dynamics between water masses from the Northfield Reservoir and the water mass in Quabbin Reservoir.

Finally, it will be necessary to have toxicology data for the probable fish species entrained in the water being transferred. This information is required because fish control options to control the introduction of undesirable fish into Quabbin Reservoir must be assessed (including assessment of effects on non-target species).

4D. EXISTING INFORMATION

Extensive water quality and aquatic ecology data exist for Quabbin Reservoir. Surveys from several stations have been conducted for approximately 10 years. Specific reports and publications are listed in Table 4-1.

Extensive water quality data for the Connecticut River and Northfield Reservoir are also available (for example, New England Research, Inc., 1973 et seq.; Texas Instruments, Inc., 1975). An up-to-date compilation of wat quality data for the Connecticut River is being conducted by Normandeau Associates, Inc. and appears in another technical memorandum.

Table 4-1. Summary of Selected Data and Information on the Aquatic Ecology of Quabbin Reservoir.

Technical Reports and Data Sources	Types of Data and Information
ickson and Reynolds, 1969 ynolds et al., 1970 w England Research, Inc., 1972a, 1972b, 1973, 1974, 1975a, 1975b, 1976, 1977, 1978, 1980 tropolitan District Commission Files	Water quality data, from various stations; includes biological, chemical and physical parameters.
w England Research, Inc. 1972a rps of Engineers, 1973 ickson et al., 1975 cker and Yale, 1971 ickson and Reynolds, 1969 ggins, 1968 ggins and Colonell, 1971	Engineering data on skimming; hydrodynamic analyses; thermal data; environmental impact assessments of out-of-basin transfers in Quabbin Reservoir.
ynolds et al., 1968 o et al., 1969 gal et al., 1969 ickson and Camougis, 1974 ickson and Clausen, 1975 ner, 1974 w England Research, Inc., 1973, 1975a, 1975b	Research reports on limnological studies; heterotrophic bacteria, phytoplankton; field and laboratory mixing studies; productivity and potential eutrophication studies; inundation of shoreline vegetation.
idges and Hambly, 1971 FW, Periodic Reports	Fisheries Data and Information

Fisheries data on Quabbin Reservoir and Northfield Reservoir are available from the Massachusetts Division of Fisheries and Wildlife and from Northeast Utilities from several reports (see Table 4-1; also, Massachusetts Division of Fisheries and Game, 1978). Fisheries data on the Connecticut River are being compiled by Normandeau Associates, Inc. and appear in another technical memorandum.

Engineering data on the proposed skimming alternative are included in the NEWS Study reports. Some of the reports (e.g., New England Research, 1972a; Hecker and Yale, 1971) also contain the results of the hydrodynamic studies.

A toxicological study on the effects of ozone and chlorine on various life stages of several fish species has been conducted at the University of Massachusetts (Coler and Asbury, 1976).

4E. EVALUATION OF INFORMATION

The existing information on the water quality of the reservoirs is adequate to assess this alternative.

The adequacy of the data base on water quality for the Connecticut River has been evaluated in the technical memorandum.

In both the donor and the receiver system the key parameters are those related to nutrients and to aquatic habitat for wildlife (see Appendix 11A).

The data base for fisheries in the reservoir is adequate. The data base for fisheries populations in the Connecticut River has been evaluated in the separate technical memorandum by Normandeau Associates, Inc.

The engineering data for the Northfield flood skimming in the NEWS Study reports (see Table 4-1) must be supplemented with additional data. The NEWS Study was conducted before the hydroelectric facility became operational. The additional engineering data should include any alternative skimming scenarios not covered in the original NEWS Study. The additional engineering data should also include hydraulic and other mechanical effects which will influence the survival potential of biota entrained in water in transit between Northfield Reservoir and Quabbin Reservoir.

Hydrodynamic data from the previous studies (see Table 4-1) are inadequate because the effects of thermal stratification and winds were not evaluated. Also these earlier studies were conducted with reservoir levels in Quabbin Reservoir which simulated the effects of the earlier drought conditions in the 1960s. Consequently, additional hydrodynamic studies will be needed to supplement the earlier studies.

Additional toxicological studies will also be needed. The toxicological study published in 1976 will need to be supplemented with data which simulate actual transit conditions (e.g., transit time, pressure, etc.) for fish eggs and larvae. Adults and larger juvenile forms can probably be eliminated by mechanical means (e.g., screens). Both chemical and mechanical means of fish control will need to be evaluated.

4F. RECOMMENDED APPROACH

The conceptual model recommended for the overall approach to this alternative attempts to integrate the various types of data required for the assessment of potential impacts. This approach was also described in detail in Section 4F of the water quality report (NER-144-01). This conceptual model integrates the data and information outlined in Section 4C (see Figure 4-1).

In addition, it will be necessary to consider several alternative models to evaluate the potential effects from the introduction of nutrients and other constituents into Quabbin Reservoir. These alternative models were also reviewed in the water quality report (see Figure 4-2 as one example of a qualitative model). The output of the water quality assessment will also be used to evaluate the projected water quality in the reservoirs with respect to aquatic habitat (Appendix 11A).

Fisheries information will be evaluated by the comparison of fish population data for the Connecticut River, Northfield Reservoir, and Quabbin Reservoir. Entrainment effects will be estimated by using engineering data plus experience from other studies (e.g., Schubel and Marcy, 1978; Goodyear, 1977).

Toxicological studies are recommended for fish eggs and larvae of selected species based on the assessment of the fisheries data. The Massachusetts Division of Fisheries and Wildlife provided guidance on the earlier study (Coler and Asbury, 1976), and would be requested to participate in species selection for future studies. Future toxicological studies should attempt to simulate transit conditions (e.g., transit time, pressures) as closely as possible.

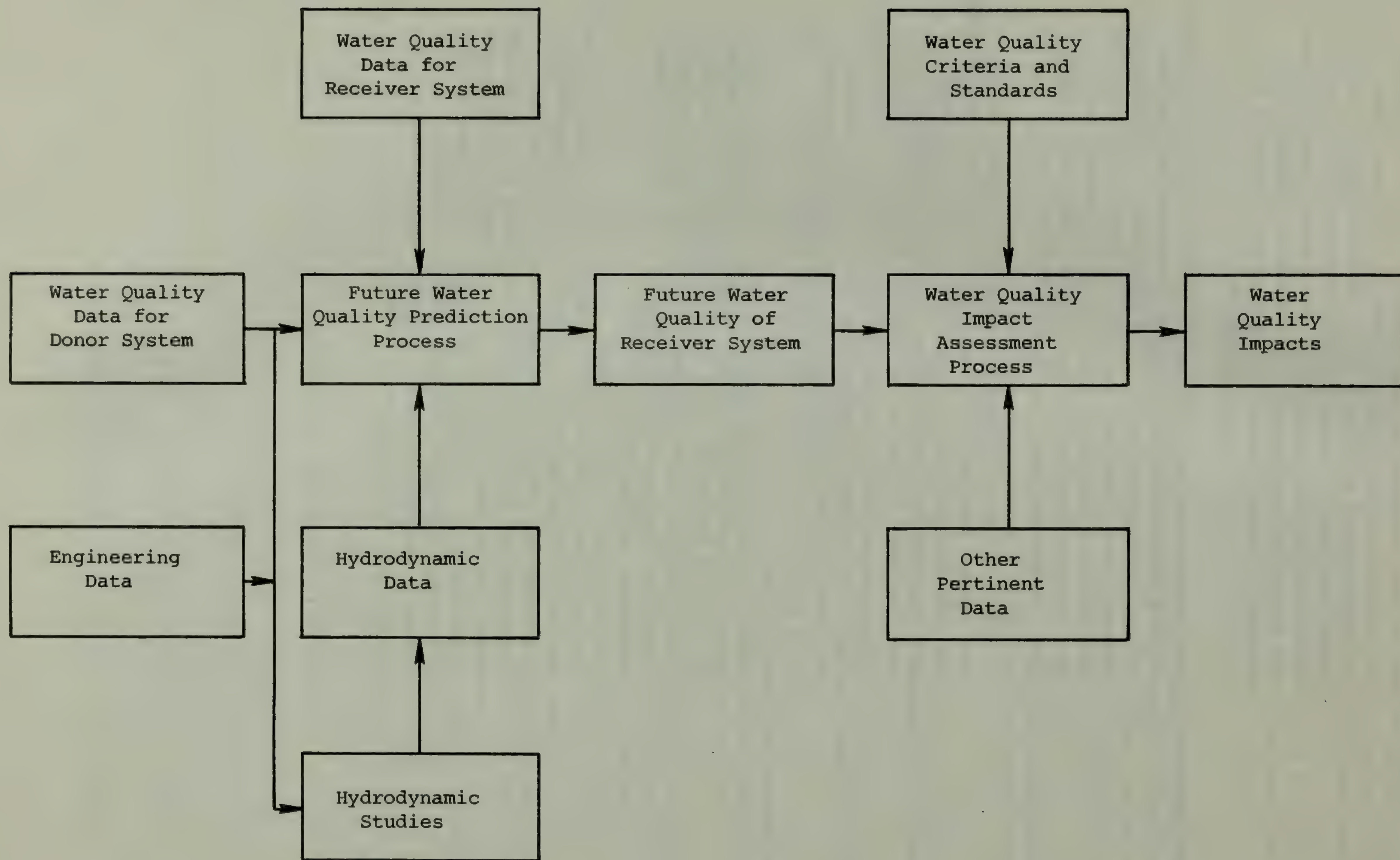

Figure 4-1. Conceptual Model of a Systems Approach to an Impact Assessment Process.

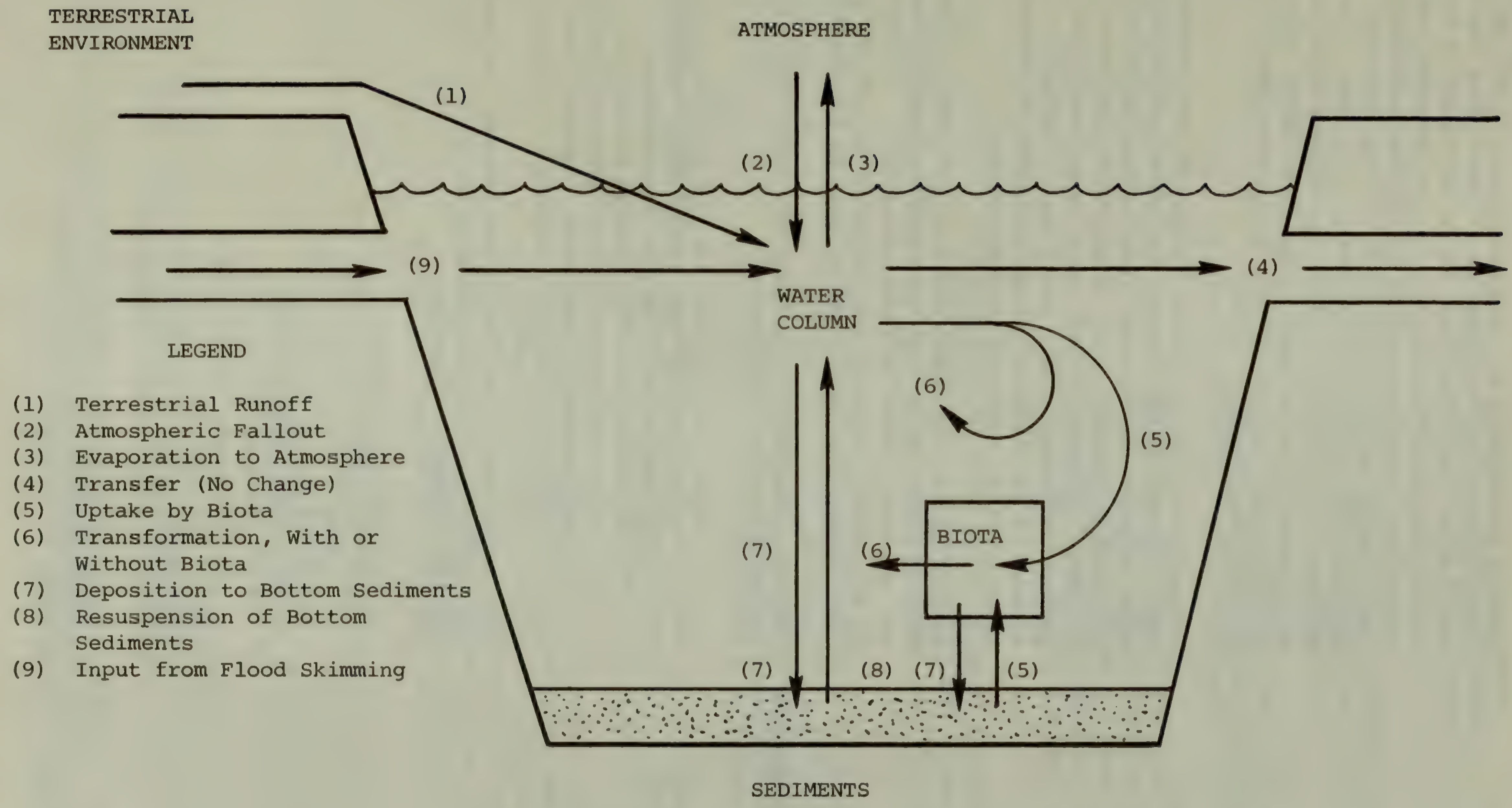

Figure 4-2. Diagram of a Multi-Compartment Model of an Aquatic System. (Modified after Erickson et al., 1975, 1978 and Camougis, 1980).

5A. INTRODUCTION

Another alternative for supplementing the MDC water supply centers on the skimming of water from the tributaries of the Connecticut River into Quabbin Reservoir during periods of high flow. This alternative was also included in the Northeastern United States Water Supply (NEWS) Study conducted by the U.S. Army Corps of Engineers and the MDC (NER, 1972a; U.S. ACE, 1973; Erickson et al., 1975). Both the Millers River and the Tully River were included in the NEWS Study. The Millers River, in particular, was investigated in some detail by the study.

5B. MAJOR ISSUES

The major ecological issues related to the reservoirs for this alternative are similar to those for the Northfield Flood Skimming Alternative (see Section 4B) and include the possible introduction of excessive nutrients (e.g., nitrogen, phosphorus) and other constituents into Quabbin Reservoir. This could lead to potential increases in the eutrophication (nutrient-enrichment and aging process) rates of the reservoirs.

Another major ecological issue is the possible introduction of undesirable fish species into Quabbin Reservoir and ultimately into Wachusett Reservoir. Introduction of undesirable species such as the carp and the lamprey could change the ecological balance in the reservoirs.

5C. NECESSARY INFORMATION

The data necessary to evaluate the major ecological issues include the following:

1. Water quality data for the tributaries.
2. Water quality data for Quabbin Reservoir.
3. Fisheries data for the tributaries.
4. Fisheries data for Quabbin Reservoir.
5. Engineering data on the proposed flood skimmings.
6. Hydrodynamic data on the proposed flood skimmings
7. Toxicology data for selected fish species.

The water quality data which are relevant to aquatic ecology and aquatic habitat include, but are not limited to, the following parameters:

- dissolved oxygen
- temperature
- pH
- turbidity
- dissolved solids
- nitrogen parameters
- phosphorus parameters

Additional details on pertinent water quality parameters are shown in Appendix 11A.

Fisheries data required for the assessment of this alternative include the following:

- density (relative numbers)
- diversity (types of species)
- spawning data and information
- creel census data

Both the water quality data and the fishery data must include information both on the tributaries and on Quabbin and Wachusett Reservoirs.

It will also be necessary to have engineering data on the proposed skimming of the tributaries. The engineering data should include:

- where the water would come from
- where the water would enter the reservoir
- details on the amounts of water transferred
- the time of year for the flood skimmings
- hydraulic data on the transit through the tunnel

Hydrodynamic data should provide information on the mixing patterns between the water masses in the reservoir and the water masses skimmed into the reservoir from the tributaries.

Finally, it will be necessary to have toxicology data for selected fish species. This is because a fish control option must be assessed (including assessment of effects on non-target species) for controlling the introduction of undesirable species into Quabbin Reservoir.

5D. EXISTING INFORMATION

Extensive data are available on the aquatic ecology and water quality of Quabbin Reservoir. Specific reports containing this information are listed in Table 4-1.

Water quality data on the tributaries were generated during the NEWS Study. In addition, the U.S. Geological Survey has compiled data for the Millers River watershed (1976). An up-to-date compilation of water quality data for the Connecticut River Tributaries has been conducted by Normandeau Associates, Inc. and appears in another technical memorandum.

Fisheries data on Quabbin Reservoir and Wachusett Reservoir are available from the Massachusetts Division of Fisheries and Wildlife. Fisheries data on the tributaries have been compiled by Normandeau Associates, Inc. and appear in another technical memorandum.

Engineering data and hydrodynamic data on the proposed skimming of the tributaries are available in the NEWS Study reports (see Table 4-1).

A toxicological study on the effects of ozone and chlorine on selected fish species has been conducted at the University of Massachusetts (Coler and Asbury, 1976).

5E. EVALUATION OF INFORMATION

Existing information on the water quality of Quabbin Reservoir is adequate for this alternative.

The adequacy of the data base on water quality for the Connecticut River Tributaries has been evaluated in a separate technical memorandum by Normandeau Associates, Inc.

In both donor and receiver systems the primary parameters are those related to nutrients and to aquatic habitat for wildlife (see Appendix 11A).

The data base for fisheries in Quabbin Reservoir and Wachusett Reservoir is adequate. The data base for fish populations in the Connecticut River Tributaries has been evaluated in a separate technical memorandum by Normandeau Associates.

The basic engineering data in the NEWS Study are adequate to assess this study. However, any alternative skimming scenarios will require additional data. Also, hydraulic and other mechanical effects on entrained biota in transit through the skimming aqueduct will need to be studied.

Hydrodynamic data from the previous studies are inadequate because the effects of thermal stratification and winds were not included. Also the studies simulated reservoir levels which existed following the drought period of the 1960s. Additional hydrodynamic modeling studies will be needed.

The toxicological studies will need to be supplemented with data which simulate the actual transit conditions (e.g., transit time, pressure, etc.) for fish eggs and larvae. Adults and larger juvenile forms can probably be eliminated by mechanical means (e.g., screens). Both chemical and mechanical means of fish control will need to be evaluated.

5F. RECOMMENDED APPROACH

The general approach to this alternative will be similar to that for the Northfield Flood Skimming Alternative. The conceptual model recommended in Section 4F will also be applied to this alternative. This conceptual model integrates the data and information outlined in Section 5 in an impact assessment process (see Figure 4-1).

In addition, it will be necessary to consider several approaches to evaluate the potential effects from the introduction of nutrients and other constituents into Quabbin Reservoir. These approaches were also discussed briefly in the water quality memorandum. Figure 4-2 is one example of a qualitative model. The output of the water quality assessments will also be used to evaluate the projected water quality in the reservoirs with

respect to aquatic habitat (Appendix 11A).

Fisheries data will be evaluated by comparing the fish population data for the tributaries and the reservoirs. Entrainment effects will be estimated by using engineering data plus experience from other studies (e.g., Schubel and Marcy, 1978; Goodyear, 1977).

Toxicological studies are recommended for fish eggs and larvae of selected species indicated by the assessment of the fisheries data. These studies should simulate transit conditions.

6A. INTRODUCTION

6A1. BACKGROUND

A watershed (drainage basin, catchment area) is the land surface from which water flows to a given point on a water course (Pereira, 1973). Watershed management is management of land surfaces within a watershed boundary to meet water-related and other objectives. The MDC has always practiced watershed management on their lands. In the earliest days, their objective was protection of high quality water supplies. They restricted public access and planted pine plantations on unused farm land to reduce erosion. Over the years the objectives have broadened to include objectives of increased water yield, improvement of forest quality, maintenance of healthy wildlife populations, and protection of an aesthetically pleasing landscape (Spencer and Walker, 1972), as well as protection of high quality water supplies. Additional emphasis has been recently placed on the water yield objective (MDC, 1979). As outlined below, the Quabbin Watershed Management Alternative will focus on increasing water yield through watershed management.

6A2. DESCRIPTION OF THE ALTERNATIVE

The Quabbin Watershed Management Alternative for increasing the MDC water supply is intensive vegetation management on MDC lands to reduce evaporation losses from the watershed and thereby increase water yield. The three land areas under consideration as specified by the Scope of Work are:

- Quabbin Reservoir watershed (upstream of Winsor Dam).
- MDC land in the Ware River watershed (upstream of Shaft 8 diversion in Barre).
- MDC land in Wachusett Reservoir watershed (upstream of Clinton Dam).

Several possible vegetation management scenarios will be considered in Phase II. These scenarios may include:

- Reducing the leaf cover (density) of existing vegetation types. Several different density levels may be evaluated.
- Replacing the existing vegetation types with another type of vegetation that uses less water.

Vegetation management affects other resources in addition to modifying water yields. For example timber products and wildlife populations,including rare and endangered species, are two resources that may be enhanced or diminished, depending on the particular management scenario.

The effectiveness of vegetation management for increasing water yield is limited by constraints imposed by other uses of a watershed such as recreational use, scientific study, administrative use, legislative restrictions, etc. A vegetative management plan for increasing water yield has to consider the other resources and uses of the watershed, and consider a specific scenario of objectives.

B. MAJOR ISSUES

Under the Quabbin Watershed Alternative there are two major ecological issues:

- The effects of vegetation management on the terrestrial ecosystems in Quabbin Reservoir, Ware River and Wachusett Reservoir watersheds.
- The effects of vegetation management on the aquatic communities in Quabbin Reservoir, Ware River and Wachusett Reservoir.

C. NECESSARY INFORMATION

Evaluation of the Quabbin Watershed Management Alternative requires data on the following parameters:

- Baseline data on the terrestrial communities (flora and fauna) of the Quabbin, Ware River and Wachusett watersheds.
- Baseline data on the aquatic communities (flora and fauna) of Quabbin, Ware River and Wachusett watersheds.
- Identification of rare and endangered species (if they exist) which might be found on MDC land within the Quabbin watershed and in the Ware River and Wachusett watersheds.
- Data on soil properties (textures, depth, water-holding capacity and erodibility) of areas to be modified.
- Specifications for a vegetation modification program.

D. EXISTING INFORMATION

6D1. TERRESTRIAL COMMUNITIES

Vegetation

Forest type mapping has been completed in the spring of 1979 on MDC lands in Quabbin Watershed except for the islands in the reservoir (Personal Communication, MDC, 3/12/80). Less precise type mapping based on 1951 and 1971 aerial photographs is available for all study areas (Noyes, 1967 and Personal Communication, SCS, 5/1/80).

Continuous forest inventory (CFI) plot data for MDC lands in the Ware River Watershed are currently being

processed and should be available soon. There is no current detailed forest type map available for the MDC lands in the Ware River Watershed (Personal Communication, MDC, 3/12/80).

There are no CFI data or current forest type maps available for the Wachusett Watershed (Personal Communication, MDC, 3/12/80).

Wetlands mapping for all three areas has been done by the National Wetlands Inventory. These maps have not been published yet but transparent overlays may be purchased (Personal Communication, U.S. FWS, 5/13/80).

Data on other components of terrestrial vegetation appears to be minimal for the three watersheds.

Soils

Soil type maps are available for the portion of Quabbin Watershed which lies in Franklin County: Prescott peninsula and the northwest part of the watershed (Fuller and Mott, 1967). None of the rest of the watershed, except for scattered farms, has been soil mapped (Personal Communication, SCS, 5/1/80).

Only small portions of the Ware River Watershed in Westminster and Rutland have been soil mapped. Soil maps are available for almost all of Wachusett Watershed (Personal Communication, SCS, 5/1/80).

Wildlife

Data on wildlife, especially game species are available for the study areas (Personal Communication, Mass. Division of Fisheries and Wildlife 7/9/80). Recent data on breeding birds are available from the Massachusetts Breeding Bird Atlas (Massachusetts Audubon Society, 1977). Specific studies have been made on the deer herd on Quabbin watershed (Jones, 1951) and on the river otter (Toll, 1961).

6D2. AQUATIC COMMUNITIES

Extensive information is available on the aquatic communities of the Quabbin Reservoir, Ware River and Wachusett Reservoir, with respect to fish, algae, plankton and invertebrates (NER, 1972a, 1972b, 1973, 1974, 1975, 1976, 1978, and 1979; MDC, 1970; Bridges and Hambly, 1971; Spencer, 1949; Toll, 1961; Woronecki, 1966; Plunkett, 1966; Rho et al., 1969; and Personal Communication, Mass. Division Fisheries and Wildlife, 5/27/80). Data on the other components of the aquatic community are sparse and qualitative. (Spencer and Walker, 1972; and MDC, 1976).

There is a substantial amount of water quality data available for the Quabbin and Wachusett Reservoirs. Over thirty years of data on a wide variety of physical, chemical and biological parameters exist for Quabbin and Wachusett Reservoirs. The following literature contains pertinent water quality data for Quabbin and Wachusett Reservoirs. Erickson and Reynolds, 1969; Hecker and Yale, 1971; New England Research, Inc. (NER), 1972a, 1972b, 1973, 1974, 1975a, 1975b 1976, 1977, 1978, 1980; Rho et al., 1969; Erickson and Camougis, 1974; Erickson and Clausen, 1975; Segal et al., 1969; Miner, 1974; Higgins and Colonell, 1971; Erickson et al., 1975; Higgins, 1968, 1970; Massachusetts Division of Fisheries and Game, 1970; Reed, 1947; Wilen, 1976; and U.S. Geological Survey, 1976.

6D3. RARE AND ENDANGERED SPECIES

Flora and fauna which have been classified in State and Federal regulations as rare and endangered species are identified in Massachusetts Division of Fisheries and Wildlife (1980) and U.S. FWS (1974, 1979). In addition, plant and animal species which have been classified as threatened, declining or limited but which have no regulatory standing are identified in SCS (1975), Mugford (1976), and Coddington and Field (1978) (see Appendix 11B). Data on rare and endangered plants in the Quabbin and Wachusett watersheds are extremely limited. Available records indicate that the only rare plants located on these watersheds were found prior to the construction of the reservoirs, and there is no record of recent rare plant surveys (Personal Communication, MNHP, 5/1/80).

Recent data on rare and endangered animals on the Quabbin and Wachusett Reservoir watersheds are limited. There is no record of recent surveys for rare animals on any of the three watersheds, (Personal Communication, MNHP, 5/1/80). However, the presence of wintering populations of bald eagles on Quabbin Reservoir has been documented on film by Jack Swedberg (Personal Communication, 5/22/80).

6E. EVALUATION OF INFORMATION

6E1. EFFECTS OF FOREST CLEARANCE

This section is the preliminary study by New England Research, Inc. of the effects of forest clearance, as specified in the Scope of Work. The study includes an estimate of potential increased yield, erosion potential and impacts on turbidity and nutrient inputs.

An estimate of the maximum potential water yield increase that may be achieved by a vegetation management program is 8 area-inches per year. This yield increase applies to intensively treated areas only. This figure is extrapolated from the Coldwell Creek experiment where a 4.5-inch increase was achieved by removing one-third of the

forest cover (Mrazik, 1974). The estimate is also based on a 40% yield increase achieved by total forest removal on a New Hampshire watershed (Hornbeck et al., 1970).

The vegetative modification, necessary to achieve this level of yield increase, would be to convert the existing dense, deep-rooted vegetative cover to a sparse, shallow-rooted vegetative cover and maintain it. Stands of short grasses, widely spaced deciduous shrubs and open stands of young hardwood trees are the types of cover that would be necessary to achieve the maximum yield increase.

The erosion potential from any land management program is primarily a function of four factors:

- Amount of soil surface physically disturbed.
- Erodibility of exposed soil.
- Amount of overland flow.
- Slope steepness

Vegetation management may result in varying degrees of exposed soil ranging from 0-100% of the area modified. Methods proposed for use on the watersheds would be those resulting in minimum soil exposure. Erodibility of exposed soil is a function of soil texture and organic matter content. Overland flow is a function of soil texture and rainfall intensity and volume.

The impact of intensive vegetation management will be to increase turbidity and nutrient inputs into the reservoirs. For example, recent research indicates that forest clearcutting in New Hampshire increased nitrate and calcium in streams draining the clearcut areas (Martin and Pierce, 1980). Baseline values for selected nutrients are available in Omernik (1977). Other research relates turbidity increases in streams to various land management activities such as logging, (for example, Dyrness, 1967). The magnitude of such increases will have to be estimated from soils data, from the vegetation management prescription and from published research results.

The drastic modifications of vegetation necessary for maximum water yield would certainly result in drastic changes in the resources being produced on the watersheds. The vegetation management scenarios, which will be considered in Phase II, will aim at somewhat less than maximum water yield increase. Correspondingly less change in the vegetation will be required and there will be less change in the resources produced.

6E2. TERRESTRIAL COMMUNITIES

Available data on forest types are probably sufficient for planning a vegetation modification program and for estimating effects of modifications if it is supplemented to pick up changes since 1971. Data on understory vegetation are inadequate for describing the terrestrial communities.

A major gap is the development of the vegetation modification program - the types and location of vegetation to be modified, the methods to be used and the resulting vegetation desired.

The soils data base is limited in areal coverage on the Quabbin and on the Ware River watersheds and is not adequate for evaluating an extensive vegetation modification program. The soils data for Wachusett watershed are adequate except for data on MDC lands in Boylston.

Information on game species of wildlife and non-game birds is probably adequate for estimating impacts from this alternative. Data on other non-game species are probably inadequate.

6E3. AQUATIC COMMUNITIES

Information on the flora and fauna of the aquatic communities is probably adequate for evaluating impacts of this alternative. Water quality data for inflowing streams may need to be supplemented.

6E4. RARE AND ENDANGERED SPECIES

Data on rare and endangered species on the study area are inadequate for evaluating impacts of the watershed management alternative.

6F. RECOMMENDED APPROACH

A major requirement for this alternative is specification of the vegetation modification scenarios. This would include specifying the yield increases needed from areas to be modified and specifying the degree to which other resources may be subordinated to water yield increases. Then areas to be modified would be delineated, specific methods would be selected and projections made of resources available after the program is implemented. Several iterations of this process may be necessary to balance water yield increases with other resources.

For development of the vegetation modification program additional soils data will be necessary and it is recommended that a reconnaissance-type soil survey be done to supplement the existing soil surveys.

Surveys for rare and endangered plant and animal species are the recommended approach to fill this data gap. This information is basic to developing the vegetation modification program.

Additional surveys necessary for the impact assessment will be surveys of understory vegetation, surveys of some non-game species and some supplemental water quality measurements on streams.

7A. INTRODUCTION

The Upper Sudbury Watershed Alternative involves the increased utilization of the Sudbury Reservoir as a water supply for the MDC system.

The Upper Sudbury Watershed has continuously served the Metropolitan Boston area as a drinking water supply, and an emergency backup water supply since 1872. Major events in the history of the seventy-five square mile Upper Sudbury Watershed are as follows (CE Maguire, Inc., 1979):

- 1872 Sudbury River Act was passed allowing limited diversion of the Sudbury River
- 1875 Construction of the Sudbury Aqueduct and Framingham Reservoirs Nos. 1, 2 and 3 was begun
- 1889 Construction of Sudbury Reservoir
- 1896 Sudbury Reservoir complete
- 1912 Use of the south branch of the Upper Sudbury Watershed discontinued because of water quality
- Sudbury Reservoir and Reservoir #3 were continued in full use.
- 1946 Quabbin Reservoir filled, reducing use of the lower quality Sudbury water
- 1947 Transfer of various Upper Sudbury River Reservoirs to recreational uses
- 1966 - 1978 Sudbury Reservoir and Reservoir #3 only utilized for emergency backup water supply.

The Commonwealth of Massachusetts Metropolitan District Commission has contracted with Parsons, Brinckerhoff, Quade and Douglas, Inc., to do a separate environmental impact study for the Sudbury Reservoir Treatment Plant. Their study will be the main assessment for the Upper Sudbury Watershed Alternative. The results of their study will be summarized and included in the Northfield study so that complete assessments of all alternatives appear in the Northfield EIR.

7B. MAJOR ISSUES

There are three major ecological issues within the Upper Sudbury Watershed Alternative:

- The effects of this alternative upon the aquatic community within the Sudbury Reservoir.
- The effects of the Sudbury Alternative upon the riparian zone and the terrestrial community adjacent to the reservoir.
- The effects of this alternative upon the downstream wildlife habitats, including the wetlands, along the Sudbury and Concord Rivers.

7C. NECESSARY INFORMATION

In order to adequately assess the Upper Sudbury Watershed Alternative, it is necessary to have the following data:

- Baseline data on the aquatic community of the Upper Sudbury Watershed with respect to its flora and fauna.
- Baseline data on the terrestrial community of the Upper Sudbury Watershed with respect to its flora and fauna.
- Data on the aquatic and terrestrial communities along the Sudbury and Concord Rivers, with emphasis upon their flora and fauna.
- Identification of wetlands along the Sudbury and Concord Rivers.
- Identification of rare and endangered species (if they exist) which may be found within the Upper Sudbury Watershed and/or along the Sudbury and Concord Rivers.
- Data on water level fluctuations within the reservoir and along the rivers due to the alternative.
- Data on changes in water quality with respect to fluctuations in the reservoir and rivers' water levels.

7D. EXISTING INFORMATION

Information of the flora and fauna of the aquatic and terrestrial communities within the Upper Sudbury Watershed and those within or along the Sudbury and Concord Rivers is limited to highly qualitative and descriptive literature (Metropolitan Area Planning Council (MAPC) 1976; McCann et al., 1972a, McCann et al., 1972c; CE Maguire, Inc., 1975; and CE Maguire, Inc., 1979).

Wetlands which are located along the Sudbury and Concord Rivers have been delineated in Larson (1973, 1976). In addition, wetlands data and maps are available through the National Wetlands Classification System (Cowardin et al., 1979) and the Regional Wetlands Coordinator (Personal Communication, U.S. Fish and Wildlife Service (U.S. FWS), 5/13/80).

Flora and fauna which have been classified in State and Federal regulations as rare and endangered species are identified in Massachusetts Division of Fisheries and Wildlife (1980) and U.S. FWS (1974, 1979). In addition, plant and animal species which have been classified as threatened, declining or limited but which have no regulatory standing are identified in U.S. Soil Conservation Service (SCS) (1975); Mugford (1976); and Coddington and Field (1978).

Data are available on fluctuations in the Sudbury Reservoir surface level (Personal Communication, Metropolitan District Commission (MDC), 5/1/80); and U.S.

Geological Survey (USGS) (1976). In addition, there are data available on river stage fluctuations for the Sudbury and Concord Rivers (Personal Communication, U.S.G.S., 5/22/80; and U.S.G.S., 1976).

Information on water quality for the Upper Sudbury Watershed is available for a number of years, from a variety of sources. McCann et al. (1972a, 1972c) contain water quality information on the Sudbury Reservoir with respect to such parameters as depth, color, drinking water classification, limnological classification, and stratification. Water quality data for thirty-five different physical and chemical parameters are available for the Sudbury Reservoir in CE Maguire, Inc., 1979. Water quality data for forty-two sites along the Sudbury and Concord Rivers and their tributaries, and for the Sudbury Reservoir are available through the STORET system of Region 1 EPA in Boston Massachusetts (Personal Communication, U.S. Environmental Protection Agency (U.S. EPA), 4/29/80). The STORET system does not contain a uniform amount of water quality information for each of the forty-two sites. Data are available on over twenty-five different water quality parameters at selected sites (U.S. EPA STORET, 1980). A Coffin and Richardson, Inc. (1980) report includes water quality information on the Upper Sudbury River Supply with respect to 25 parameters, identifies pollution sources on the Upper Sudbury Watershed, and identifies those parameters requiring treatment if this supply is to be utilized for drinking water. The U.S. Geological Survey report, Water Resources Data for Massachusetts and Rhode Island, Water Year 1975, also contains pertinent water quality information. In addition, Wilen (1976) reviews water quality data for the Sudbury Reservoir and the Concord River on the parameter of organic color.

7E. EVALUATION OF INFORMATION

Information on the flora and fauna of the terrestrial and aquatic communities in the Upper Sudbury Watershed and the Sudbury and Concord River areas is limited, highly qualitative, and descriptive. A preliminary analysis of the existing information indicates that there is no quantitative or analytical data available.*

There is no record of any recent surveys for rare and endangered plants and animals on the Upper Sudbury Watershed (Personal Communication, Massachusetts National Heritage Program (MNHP), 5/1/80). Existing data on rare and endangered species consist of general descriptive evaluations with little or no site specific information.*

Adequate data exist to effectively identify wetlands along the Sudbury and Concord Rivers.

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* New information is being reviewed by other MDC consultants.

There are sufficient data available on the water quality of the Sudbury Reservoir; however, water quality data liste in the memo for the downstream areas of the Sudbury and Concord Rivers are intermittent and outdated.*

7F. RECOMMENDED ACTION

The evaluation of the existing information indicates that there are adequate data to determine the water quality effects of the Upper Sudbury Watershed Alternative on the aquatic communities of the Sudbury Reservoir.

However, additional data on the water quality of the downstream reaches of the Sudbury and Concord Rivers other than those listed will be needed. This data may exist, but it was beyond the scope of this phase of the study.

In addition, data on the flora and fauna of the aquatic and terrestrial communities of the Upper Sudbury Watershed and the downstream areas of the Concord and Sudbury Rivers will be needed, particularly with respect to rare and endangered species.

A separate EIR is being prepared for the Sudbury Reservoir Treatment Plant. Both the engineering and the environmenta data will be reviewed in that project. Consequently, no additional field studies are recommended under the Northfield EIR study for this alternative. It is recommended that the data and conclusions from the Sudbury EIR study be used to describe this alternative within the context of the Northfield EIR. This approach would avoid needless duplication of effort.

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* New information is being reviewed by other MDC consultants.

8A. INTRODUCTION

This alternative includes the potential use of abandoned and reserve water supplies in eastern Massachusetts.

One potential source of supply entails the reactivation of abandoned ground- and surface water supplies within the communities of the Metropolitan Water District (MWD). An engineering report on these supplies has been prepared recently for the U.S. Army Corps of Engineers (Coffin and Richardson, Inc., 1980), see Table 8-1.

8B. MAJOR ISSUES

The main issue concerns possible deleterious effects of surface water drawdowns on plant and wildlife populations of both surface water supply areas and adjacent wetlands. These surface water drawdowns can be the result of two things:

1. the use of surface waters as drinking water supplies.

2. high volume withdrawal of adjacent groundwater supplies.

8C. NECESSARY INFORMATION

Information that will facilitate identification of aquatic and nearby terrestrial communities is needed for potential surface water supplies and for other surface waters whose levels may be affected by high volume groundwater withdrawal. In addition, information on wetland communities located adjacent to the surface water supplies is needed. Data on habitat requirements are needed for plants and wildlife populations which may be affected by this alternative, with emphasis on those of rare or endangered status. Engineering data, especially water level fluctuations and durations, are required to assess effects on fish and wildlife in both the surface waters under consideration and the adjacent wetlands. This analysis is needed only for feasible water supply areas (see Section 8F).

8D. EXISTING INFORMATION

A map delineating freshwater wetlands is available for Massachusetts based on previously prepared land-use and vegetative cover maps (Larson, 1973).

Physical, biological, and land-use information on surface waters in Essex, Plymouth, Middlesex, Bristol, Worcester, Norfolk, and Suffolk counties is available in a series of six publications (McCann, et al., 1972a, 1972b, 1972c, 1972d, 1972e, 1972f). Appendix 11C illustrates the information available in this report.

Information is available concerning rare and endangered plant and wildlife species of Massachusetts (Soil Conservation Service, 1975; Mugford, 1976; Coddington and Field, 1978; U.S. FWS, 1979; Massachusetts Division of Fisheries and Wildlife, 1980). This information includes species name, description of known range,

Table 8-1. Nine Abandoned Water Sources in Eastern Massachusetts Identified as Potential Drinking Water Supplies by Coffin and Richardson, Inc. (1980) for U.S. Army Corps of Engineers.

- Charles River Wells
- Chicopee River Canal
- Cooley Brook and Morton Brook Reservoirs
- Dedham Avenue Supply
- Buckmaster Pond
- Lake Cochituate Wells
- Newton Water Works Reservation
- Rosemary Brook Supply
- Upper Sudbury River Supply

status (endangered or threatened), and limited information regarding habitat requirements.

Available engineering data include yield estimates for abandoned or reserve surface waters of Massachusetts (Coffin and Richardson, Inc., 1980). These yield estimates are either the most recent ones available or are derived using generalized watershed yield curves. Also, maps are available illustrating such engineering data as generalized ground and surface water potential for Massachusetts, source location of ground and surface water supplies, and intertown and interbasin transfer (WFEM, 1978).

Additional water resources information is available for Massachusetts' ground and surface water sources including stream discharge measurements, surface areas and contents of lakes and reservoirs, and water levels for wells (U.S.G.S., 1976).

8E. EVALUATION OF INFORMATION

Existing ground- and surface water sources in eastern Massachusetts have been identified as potential drinking water supplies. However, no specific water sources have been identified as being feasible with respect to engineering considerations. More complete information is required regarding the specific potential of existing water sources before this alternative can be accurately evaluated.

Data gaps exist in the available information needed to identify the aquatic, wetland, and terrestrial habitat characteristics of those communities that may be affected by surface water drawdowns.

Much of the available information on rare and endangered plant and wildlife species concerns their range, status and typical habitat (see Section 8D). More information is needed regarding the habitat requirements of these and all other plant and wildlife populations that may be affected by this alternative.

Estimates of yield for nine potential surface water supplies are reported in the Coffin and Richardson publication (1980) but are either based on dated estimates or are derived using generalized watershed yield curves. Generalized ground- and surface water potentials for all of Massachusetts are provided by WFEM (1972), however, the data are not up to date. Water resources information provided by the U.S.G.S. (1976) Water Resources Division is among recent engineering data available for surface and groundwater sources in Massachusetts. It provides engineering data concerning surface water level fluctuations and durations needed to assess impacts on fish and wildlife in both surface water sources under consideration and the adjacent wetlands.

8F. RECOMMENDED APPROACH

As discussed in Section 8E, many gaps exist in the information needed to assess this alternative. Engineering studies are recommended in order to specifically identify water supplies as being feasible with respect to engineering considerations. Once these are completed, the following sets of information need to be obtained:

1. Information that would facilitate identification of aquatic, wetland, and terrestrial communities that may be affected.

2. Specific information on plant and animal species of the communities that may be affected.

3. More complete information on habitat requirements of plant and wildlife populations that may be affected (especially rare and endangered species).

4. More up to date engineering information concerning surface level fluctuations and durations needed to assess impacts on fish and wildlife in both surface water sources and adjacent wetlands.

9A. INTRODUCTION

This alternative includes the potential use of groundwater sources in eastern Massachusetts not considered in the previous alternative. These other sources include the groundwater aquifers in Plymouth County (WFEM, 1978).

9B. MAJOR ISSUES

The main issue concerns possible deleterious effects of surface water drawdowns on plant and wildlife populations in both surface waters and other wetland and terrestrial areas. These surface water drawdowns can be the result of high volume withdrawal of groundwater supplies located adjacent to the wildlife communities.

9C. NECESSARY INFORMATION

Information that will facilitate identification of aquatic and nearby terrestrial communities is needed for potential surface water supplies and for other surface waters whose levels may be affected by high volume groundwater withdrawal. In addition, information on wetland communities located adjacent to the surface water supplies is needed. Data on habitat requirements are needed for plants and wildlife populations which may be affected by this alternative, with emphasis on those of rare or endangered status. Engineering data, especially water level fluctuations and durations, are required to assess effects on fish and wildlife in both the surface waters under consideration and the adjacent wetlands. This analysis is needed only for feasible water supply areas (see Section 8F).

9D. EXISTING INFORMATION

A map delineating freshwater wetlands is available for Massachusetts based on previously prepared land-use and vegetative cover maps (Larson, 1973).

Physical, biological, and land-use information on surface waters in Essex, Plymouth, Middlesex, Bristol, Worcester, Norfolk, and Suffolk counties is available in a series of six publications (McCann, et al., 1972a, 1972b, 1972c, 1972d, 1972e, 1972f). Appendix 11C illustrates the information available in these reports.

Information is available concerning rare and endangered plant and wildlife species of Massachusetts (Soil Conservation Service, 1975; Mugford, 1976; Coddington and Field, 1978; U.S. FWS, 1979, Massachusetts Division of Fisheries and Wildlife, 1980). This information includes species name, description of known range, status (endangered or threatened), and limited information regarding habitat requirements.

Groundwater resources information is available for various sections of Plymouth County in four Hydrologic Investigations Atlases (Williams, 1968; Williams and Tasker, 1974a, 1974b, 1977). Specifically, these sections are the Ten Mile and Taunton River basins, Weir River to Jones River basins, Plymouth River to Weweantic River basins, and the northwest shore basin of Buzzard's Bay.

Engineering data on water levels of groundwater sources are available for all of Massachusetts (U.S.G.S., 1976). In addition, maps are available illustrating such engineering data as generalized groundwater potential for Massachusetts, source location, and intertown transfer (WFEM, 1978).

9E. EVALUATION OF INFORMATION

Existing groundwater sources in eastern Massachusetts have been identified as potential drinking water supplies. However, no specific water sources have been identified as being feasible with respect to engineering considerations. More complete information is required regarding the specific potential of existing water sources before this alternative can be accurately evaluated.

Water resources information provided by U.S.G.S. (1976) is among recent engineering data available for groundwater sources in Massachusetts, and provides information concerning water level fluctuations and durations. These data are useful in assessing impacts of high volume groundwater withdrawal.

Generalized groundwater potentials for all of Massachusetts are provided by WFEM (1978). This report provides needed information on the Plymouth County aquifers. Additional Plymouth County groundwater resource information is provided by the four U.S.G.S. Hydrologic Investigations Atlases (Williams, 1968; Williams and Tasker, 1974a, 1974b, 1977). However, these data are not up to date.

9F. RECOMMENDED APPROACH

The recommended approach for this alternative includes the following actions:

1. Identify specific groundwater resources in Eastern Massachusetts not considered in the previous alternative (Abandoned and Reserve Sources) that are feasible from an engineering perspective. These feasibile water supplies could be used to augment the MWD system.

2. When these groundwater sources are identified, an ecological survey program should be undertaken so that needed sets of information can be obtained, including:

   - Information that would facilitate identification of aquatic, wetland, and terrestrial communities that may be affected.

   - Specific information on plant and animal species of the communities that may be affected.

   - More complete information on habitat requirements of plant and wildlife populations that

may be affected (especially rare and endangered species).

- More up to date engineering information concerning surface level fluctuations and durations needed to assess impacts on fish and wildlife in both surface water sources and adjacent wetlands.

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11A. WATER QUALITY CRITERIA FOR AQUATIC LIFE

11A1. INTRODUCTION

This appendix summarizes federal and state water quality criteria for preservation of aquatic life. Federal water quality criteria have been established for use by states to regulate and control water pollution.

11A2. WATER QUALITY CRITERIA

The Environmental Protection Agency (EPA) has identified maximum concentration levels of water quality criteria necessary to preserve and protect aquatic life (Table 11-1). Although nonregulatory, Water Quality Criteria (1976), known as the "Red Book", establishes guidelines for specific EPA water quality programs and for states to regulate effluent discharge.

Maximum criteria for some pollutants (including lead, silver, zinc, copper, selenium and petrochemicals) are established for a body of water by performing a bioassay on a sensitive resident species.

Mixing zones are defined as a place where wastes and water mix, not as effluent treatment sites. Mixing zones should be located where there is less potential for hazard to the biota.

Temperature limits are established at levels within lethal limits for the most sensitive important species. Important considerations are (1) effects of temperature changes during the reproductive season on reproductive functions, such as spawning and egg growth, (2) preservation of normal species diversity and (3) prevention of nuisance species.

11A3. WATER QUALITY STANDARDS OF MASSACHUSETTS (1978)

<u>Objectives</u>

Federal legislation has provided the guidelines for states to legislate water quality standards based on (1) the designated "use" of a body of water, and (2) the maximum allowable concentration levels of pollutants to maintain the designated "use" (U.S. EPA, 1978). The Massachusetts standards establish effluent limitations and regulate municipal discharges, to minimize pollutant impact on the quality of receiving waters.

<u>Inland Water Classification</u>

Designated "use" classifications are defined by the most sensitive use of the water body.

- Class A waters - source of public water supply

Table 11-1. Water Quality Criteria for Aquatic Life (MDWPC, 1978)

Parameters:	Parameters:
Alkalinity	Demeton
Ammonia	Endosulfan
Arsenic	Endrin
Beryllium	Guthion
Cadmium	Heptachlor
Chlorine	Lindane
Chromium	Malathion
Color (plant photosynthesis)	Methoxychlor
Copper	Mirex
Cyanide	Parathion
Total dissolved gases	Toxaphene
Iron	pH
Lead	Phosphorus (elemental)
Mercury	Phthalate esters
Mixing zones	Polychlorinated biphenyls
Nickel	Selenium
Oil and Grease	Silver
Dissolved oxygen	Solids (suspended, settleable) and turbidity
Aldrin/Dieldrin	Sulfide - hydrogen sulfide
Chlordane	Temperature
DDT	Zinc

- Class B waters - protection and propagation of fish, other aquatic life and wildlife, and for primary and secondary contact recreation.

- Class C waters - protection and propagation of fish and secondary contact recreation.

Table 11-2 lists water quality parameters for each designated use classification.

11A4. SOME FACTORS AFFECTING RESPONSE OF AQUATIC LIFE TO POLLUTANTS

Time-concentration ratios can profoundly affect the toxicity of pollutants to aquatic organisms. Some organisms can build up a tolerance to concentrations which would markedly affect a nontolerant organism. The species, size, age and physiological condition of the organism can change response to substances. The organism's response can be affected by the physical and chemical composition of a water supply, i.e., low oxygen concentration, soft water and increased temperature can all increase susceptibility of aquatic organisms to toxic substances (McKee and Wolf, 1963).

The synergistic, or combined, action of certain substances can have much greater impact on an organism than just an additive reaction. Hydrographical features of a water system and changes in water level affect an organism's physiological response to toxic substances (McKee and Wolf, 1963). Pollution tolerance can give competitive advantage to one species over another (U.S. Army Corps of Engineers, 1975).

11A5. TOXIC POLLUTANTS

As promulgated by the Clean Water Act of 1977, 65 toxic pollutants have been identified. Data has been supplied where possible on the effects of these substances on human health and aquatic life. Aquatic organisms are considered able to tolerate fluctuation of substances in water and to tolerate brief exposures to increases of toxic substances due to fluctuations. Therefore, criteria for aquatic life are estimated (1) on an average concentration over a 24-hour period and (2) on a maximum concentration level not to be exceeded (U.S. EPA, 1979a).

In Table 11-3, these substances are identified, and indication is made for pollutants having insufficient available data to establish concentration levels necessary to protect aquatic life.

Table 11-2. Water Quality Standards of Massachusetts (1978): Water Use Classifications and Parameters for Inland Waters.

Parameters	Class A	Class B	Class C
Aesthetics	X	X	X
Radioactive substances	X	X	X
Tainting substances	X	X	X
Color, turbidity, total suspended solids	X	X	X
Oil and grease	X	X	X
Nutrients	X	X	X
Other constituents	X	X	X
Dissolved oxygen	X	X	X
Temperature	X	X	X
pH	X	X	X
Total coliform bacteria	X		
Turbidity	X		
Total dissolved solids	X		
Chlorides	X		
Sulfates	X		
Nitrate	X		
Fecal coliform bacteria		X	X

Table 11-3. Clean Water Act: Water Quality Criteria Availability for 65 Toxic Pollutants - Freshwater Aquatic Life Criteria (U.S. EPA, 1978, 1979a, b, c).

ID: Insufficient data available on effects on aquatic life

Acenaphthene
Acrolein
Acrylonitrile
Aldrin/Dieldrin
Antimony
Arsenic
Asbestos (ID)
Benzene
Benzidine (ID)
Beryllium
Cadmium
Carbon Tetrachloride
Chlorodane
Chlorinated benzines
Chlorinated ethanes
Chloroalkylethers (ID)
Chlorinated naphthalenes
Chlorinated phenols
Chloroform
2-chlorophenol
Chromium
Copper
Cyanide
DDT
Dichlorobenzenes
Dichlorobenzidine (ID)
Dichloroethylenes
2,4-dichlorophenol
Dichloropropanes/propenes
2,4-dimethylphenol
Dinitrotoluene
Diphenylhydrazine
Endosulfan
Endrin
Ethylbenzene (ID)
Fluoranthene
Haloethers
Halomethanes
Heptachlor
Hexachlorobutadiene (ID)
Hexachlorocyclohexane
Hexachlorocyclopentadiene
Isophorone
Lead
Mercury
Naphthalene (ID)
Nickel
Nitrobenzene
Nitrophenols

Nitrosamines (ID)
Pentachlorophenol
Phenol
Phthalate esters (ID)
Polychlorinated biphenyls (PCB's)
Polynuclear aromatic hydrocarbons (ID)
Selenium
Silver
2,3,7,8-tetrachloro-dibenzo-p-dioxin (ID)
Tetrachlorethylene
Thallium (ID)
Toluene
Toxaphene
Trichloroethylene
Vinyl chloride (ID)
Zinc

11A6. REFERENCES

Massachusetts Division of Water Pollution Control (MDWPC), September 1978. Massachusetts Water Quality Standards. Massachusetts Water Resources Commission, Boston, Massachusetts.

McKee, Jack Edward and Harold W. Wolf, Eds. 1963. Water Quality Criteria. 2nd Edition. The Resources Agency of California, California State Water Resources Control Board, Sacramento, California.

Metcalf and Eddy, Inc. October 1975. Wastewater Engineering and Management Plan for Boston Harbor - Eastern Massachusetts Metropolitan Area (EMMA Study), Vol. 13A, Biological Impact Analysis..

United States Environmental Protection Agency (U.S. EPA). July 1976. Quality Criteria for Water. Washington, D.C.

United States Environmental Protection Agency (U.S. EPA). July 10, 1978. Water Quality Standards (Proposed Rules). Federal Register, Vol. 43, No. 132, pp. 29588-29592.

United States Environmental Protection Agency (U.S. EPA). March 15, 1979a. Part V. Water Quality Criteria. Request for Comments. Federal Register, Vol. 44, No. 52, pp. 15926-15981.

United States Environmental Protection Agency (U.S. EPA). July 25, 1979b. Water Quality Criteria; Availability. Federal Register, Vol. 44, No. 144, pp. 43660-43697.

United States Environmental Protection Agency (U.S. EPA). October 1, 1979c. Water Quality Criteria; Availability. Federal Register, Vol. 44, No. 191, pp. 56628-56657.

11B. RARE AND ENDANGERED SPECIES

11B1. BACKGROUND INFORMATION

The following information has been used in the identification of rare and endangered plant and animal species in Massachusetts:

- Threatened Species in Massachusetts. 1975. A list compiled by the U.S. Department of Agriculture, Soil Conservation Service, Amherst, Massachusetts.

- Fish and Wildlife Existing in Limited Numbers in Massachusetts. Paul S. Mugford, 1976, Massachusetts Division of Fisheries and Wildlife, 100 Cambridge Street, Boston, Massachusetts 02202.

- Rare or Declining Vascular Plants of Massachusetts. (Cover: Rare and Endangered Vascular Plant Species in Massachusetts). Jonathan Coddington and Katherine G. Field, 1978; prepared by The New England Botanical Club in Cooperation with the U.S. Fish and Wildlife Service.

- List of Endangered and Threatened Wildlife and Plants, Republication. Department of the Interior, Fish and Wildlife Service, 1979; Federal Register, Wednesday, January 17, 1979, Part II.

- Endangered and Threatened Species in Massachusetts. 1979. A list compiled from the January 17, 1979 Federal Register by the U.S. Fish and Wildlife Service, Newton Corner, MA.

- Endangered Wildlife and Wild Plants. 1980. The regulation promulgated by the Massachusetts Board of Fisheries and Wildlife. 321CMR8.01.

- Personal communication with Martha Fisher, Massachusetts Natural Heritage Program, May 1, 1980.

- Personal communications with Jack Swedberg and Bradford Blodgett, Massachusetts Division of Fisheries and Wildlife, 1980.

11B2. EVALUATION OF BACKGROUND INFORMATION

It is important to recognize the existence of two groups of organisms. The first group consists of species which are listed officially as being in an endangered or threatened status within specified areas of their geographic ranges. Both the U.S. Government and the Commonwealth of Massachusetts have official lists.

The second group consists of biological species which various organizations have determined to be rare or limited in their numbers and hence in need of protection. Thus there are "official" and "unofficial" lists of biological species considered to be in a rare, endangered or threatened status in Massachusetts. For purposes of this document, the term RARE will be used as a generic classification for all species on both official and unofficial lists. Table 11-4 is a summary of numbers of RARE plant species in Massachusetts listed in various sources. Table 11-5 is a similar summary of numbers of RARE animal species. Tables 11-6 through 11-10 give common and scientific names of plant and animal species on the various official and unofficial lists.

A search of the data base on RARE species at the Massachusetts Natural Heritage Program revealed only four formal records of RARE species in the Quabbin area, one in the Wachusett Reservoir area and one in the Ware River Watershed area. The latest record is 1971 and most of the records date back before the reservoirs were flooded.

Current informal study of Quabbin wildlife by Jack Swedberg, Photographer, Massachusetts Division of Fisheries and Wildlife has documented some RARE birds and mammals. However, no systematic surveys of RARE plants and animals appear to have been made recently on the three watersheds.

Table 11-4 Numbers of RARE Plant Species in Massachusetts on Various Lists.

Sources	Endangered List	Threatened List	Other Lists
U.S. Dept. Interior, Fish & Wildlife Service, Federal Register (1979)	None	None	Not Applicable
Commonwealth of Massachusetts Fisheries & Wildlife Board, 321CMR8.01 (1980)	Whorled Pogonia	None	Not Applicable
New England Botanical Club in Cooperation with U.S. F.W.S. (Coddington & Field, 1978)	Not Applicable	Not Applicable	242 Species in 12 Classification Criteria
U.S. Dept. Agriculture Soil Conservation Service (1975)	None	3*	27 Species in Various Categories

* Status is not the same as that in the USFWS Federal Register List.

Table 11-5 Numbers of RARE Animal Species in Massachusetts on Various Lists.

Sources	Endangered List	Threatened List	Other Lists
U.S. Dept. of Interior, Fish & Wildlife Service Federal Register (1979).	15	1	Not Applicable
Commonwealth of Massachusetts Fisheries & Wildlife Board 321CMR8.01 (1980)	16	1	Not Applicable
Commonwealth of Massachusetts Division of Fisheries & Wildlife (Mugford, 1976)	13*	6*	42 Species in Various Categories
U.S. Dept. of Agriculture Soil Conservation Service, (1975)	None	14*	44 Species in Various Categories

* Status is not the same as that in the USFWS Federal Register List.

Table 11-6 List of "Threatened" Plant Species on the U.S. Department of Agriculture, S.C.S. List (1975).

Common Name	Scientific Name
Ramshead Lady's-slipper	(Cypripedium arietinum)
Showy Lady's-slipper	(Cypripedium reginae)
Ginseng	(Panax quinquefolius)

Table 11-7. List of Engdangered and Threatened Species in Massachusetts compiled by the U.S. Fish and Wildlife Service (1979).

Common Name	Scientific Name	Status
FISHES:		
Sturgion, shortnose	*Acipenser brevirostrum*	E
REPTILE:		
Turtle, green	*Chelonia mydas*	T
Turtle, hawksbill	*Eretmochelys imbricata*	E
Turtle, leatherback	*Dermochelys coriacea*	E
Turtle, loggerhead	*Caretta caretta*	E
Turtle, Atlantic ridley	*Lepidochelys kempii*	E
BIRDS		
Eagle, bald	*Haliaeetus leucocephalus*	E
Falcon, American peregrine	*Falco peregrinus anatum*	
Falcon, Arctic peregrine	*Falco peregrinus tundrius*	E
MAMMALS:		
Cougar, eastern	*Felis concolor cougar*	E
Whale, blue	*Balaenoptera musculus*	E
Whale, finback	*Balaenoptera physalus*	E
Whale, humpback	*Megaptera novaeangliae*	E
Whale, right	*Eubalaena spp.* (all species)	E
Whale, sei	*Balaenoptera borealis*	E
Whale, sperm	*Physeter catodon*	E
MOLLUSKS		
None		
PLANTS:		
None		

Table 11-8. List of Endangered and Threatened Species in Massachusetts specified by the Commonwealth of Massachusetts (1980).

Common Name	Scientific Name	Status
FISHES:		
Sturgeon, shortnose	Acipenser brevirostrum	E
REPTILES:		
Turtle, green	Chelonia mydas	T
Turtle, hawksbill	Eretmochelys imbricata	E
Turtle, leatherback	Dermochelys coriacea	E
Turtle, loggerhead	Caretta caretta	E
Turtle, Atlantic ridley	Lepidochelys kempii	E
BIRDS		
Eagle, bald	Haliaeetus leucocephalus	E
Falcon, American peregrine	Falco peregrinus anatum	E
Falcon, Arctic peregrine	Falco peregrinus tundrius	E
MAMMALS		
Cougar, eastern	Felis concolor cougar	E
Whale, blue	Balaenoptera musculus	E
Whale, finback	Balaenoptera physalus	E
Whale, humpback	Megaptera novaeangliae	E
Whale, right	Eubalaena spp. (all species)	E
Whale, sei	Balaenoptera borealis	E
Whale, sperm	Physeter catodon	E
MOLLUSKS		
None		
PLANTS		
Whorled Pogonia	Isotria medeoloides	E

Table 11-9. List of Endangered and threatened animal species in Massachusetts from Mugford (1976).

Common Name	Scientific Name	Status
Shortnose sturgeon	Acipenser brevirostrum	E
Atlantic sturgeon	Acipenser oxyrhynchus	E
Atlantic salmon	Salmo salar	E
Trout-perch	Percopsis omiscomaycus	E
Eastern cougar	Felis concolor couguar (sic)	E
Indiana bat	Myotis sodalis	E
Southern bald eagle	Haliaeetus l. leucocephalus	E
American perigrine falcon	Falco peregrinus anatum	E
Plymouth red-bellied turtle	Chrysemys rubiventris bangsi	E
Bog turtle	Clemmys muhlenbergii	E
Timber rattlesnake	Crotalus h. horridus	E
Blue-spotted salamander	Ambystoma laterale	E
Spotted salamander	Ambystoma maculatum	T
Marbled salamander	Ambystoma opacum	T
Atlantic green turtle	Chelonia m. mydas	T
Atlantic hawksbill	Eretmochelys i. imbricata	T
Atlantic loggerhead	Caretta c. caretta	T
Atlantic ridley	Lepidochelys Kempi	T
Atlantic leatherback	Dermochelys c. coriacea	E

Table 11-10. List of Endangered and Threatened Species in Massachusetts from U.S. Soil Conservation Service (1975).

Common Name	Scientific Name
American perigrine falcon	Falco perigrinus anatum
Bald eagle	Haliaetus l. leucocephalus
Ipswich sparrow	Passerculus princeps
Emerald shiner	Notropis atherinoides
Atlantic sturgeon	Acipenser oxyrhynchus
Shortnose sturgeon	Acipenser brevirostrum
Trout-perch	Percopsis omiscomaycus
Eastern cougar	Felis concolor cougar
Indiana bat	Myotis sodalis
Timber rattlesnake	Crotalus horridus horridus
Atlantic hawksbill seaturtle	Eretmochelys imbricata imbricata
Bog turtle	Clemmys muhlenbergi
Leatherback sea turtle	Dermochelys coriacea coriacea
Ridley sea turtle	Lepidochelys kempi

11C. ECOLOGICAL INFORMATION ON SURFACE WATERS IN EASTERN MASSACHUSETTS

This appendix summarizes the specific ecological information available for surface waters in Essex, Plymouth, Middlesex, Bristol, Dukes, Nantucket, Worcester, Norfolk and Suffolk Counties, (McCann *et al*., 1972a, 1972b, 1972c, 1972d, 1972e, and 1972f). See Table 11-11.

Table 11-11. Available Ecological Information on Surface Waters in Eastern Massachusetts.

- Surface area in acres
- Altitude above sea level in feet
- Mean and Maximum depth in feet
- Whether thermally stratified or not
- Limnological classification

  eutrophic (highly productive, aged)
  mesotrophic (moderately productive, usually thermally stratified)
  oligotrophic (of low productivity, thermally stratified)
  bog (a boggy shore of low productivity)
  brackish (tidal)

- Pond type

  natural
  artificial (with inlet)
  enhanced (deepened)
  quarry
  beaver dam
  backwater (from river flow)
  borrow pit (caused by construction)
  tidal
  kettlehole (without inlet)

- Whether a map is available or not
- Water type

  cold (suitable for trout)
  cold-warm (both cold and warm water fish species)
  warm (warm water fish, only)
  brackish (mixture of salt and freshwater)

- Productivity (in pounds of fish per acre)
- Subjective evaluation of relevant abundance of emergent and submergent plant growth (scant, common, abundant)
- Stocked

  cold water fish
  warm water fish
  cold and warm water fish
  none

- Shoreline length in miles

- Shoreline type

  high (bank steep, land never floods)
  low (bank shallow, land frequently floods)
  intermediate (intermediate slope and/or occasionally flooded)

- Percent of shoreline subject to the following uses:

  wooded
  park
  swamp

- Fish Management

  bullhead
  chain pickerel
  largemouth bass
  smallmouth bass
  white perch
  yellow perch

- Distance from town

- Subjective evaluation of degree of body use on a seasonal basis (light, moderate, heavy, exclusive) for each use:

  wildlife
  hunting
  fishing

- Percent of shoreline being developed for each use:

  park
  swamp
  vacant

11C1. REFERENCES

McCann, James A., Hermon J. Coven, Robert P. Corrinet, and Paul E. Ostroski. 1972a. An Inventory of the Ponds, Lakes and Reservoirs of Massachusetts - Worcester County. Community Resource Development Program, Cooperative Extension Service, University of Massachusetts, U.S. Department of Agriculture and County Extension Services Cooperating. Amherst, Massachusetts.

McCann, James A., John B. Dixon, and Robert W. Schleyer. 1972b. An Inventory of Ponds, Lakes, and Reservoirs of Massachusetts - Essex County. Water Resources Research Center. University of Massachusetts, Amherst, Massachusetts.

McCann, James A., John B. Dixon and Robert W. Schleyer. 1972c. An Inventory of the Ponds, Lakes, and Reservoirs of Massachusetts - Middlesex County. Community Resource Development Program, Cooperative Extension Service, University of Massachusetts, U.S. Department of Agriculture and County Extension Services Cooperating. Amherst, Massachusetts.

McCann, James A., John B. Dixon, and Robert W. Schleyer. 1972d. An Inventory of the Ponds, Lakes and Reservoirs of Massachusetts - Norfolk and Suffolk Counties. University of Massachusetts, U.S. Department of Agriculture and County Extension Services Cooperating. Amherst, Massachusetts.

McCann, James A., George E. Wood, and Edward E. Kraus. 1972e. An Inventory of the Ponds, Lakes, and Reservoirs of Massachusetts - Plymouth County. Community Resource Development Program, Cooperative Extension Service, University of Massachusetts, U.S. Department of Agriculture and County Extension Services Cooperating. Amherst, Massachusetts.

McCann, James A., George E. Wood and Edward E. Kraus. 1972f. An Inventory of the Ponds, Lakes, and Reservoirs of Massachusetts - Bristol, Dukes, and Nantucket Counties. Community Resources Development Program, Cooperative Extension Service, University of Massachusetts, U.S. Department of Agriculture and County Extension Services Cooperating. Amherst, Massachusetts.

REPLIES TO COMMENTS
ON DRAFT TECHNICAL MEMORANDUM
ECOLOGY - RESERVOIRS, SURFACE AND GROUNDWATER
SUPPLIES, NORTHFIELD EIR

COMMENTS BY NORTHFIELD CITIZENS ADVISORY COMMITTEE

Note: Questions are reproduced as received except for minor editorial corrections. Page numbers refer to the draft memorandum pages.

QUESTION: (1) The absence of a complete list of references makes it almost impossible to evaluate the coverage of previous studies listed because many are not cited correctly or are missing.

REPLY: The list of references has been supplemented and is now complete. See the revised technical memorandum, Page 63.

QUESTION: (2) Table 1-1, p.2, and Table 1-2, p.4: since Parsons-Brinkerhoff will be undertaking studies of the Upper Sudbury Watershed Alternative, how will the results of their research be integrated into the Northfield Environmental Impact Report?

REPLY: The Parsons-Brinkerhoff EIR study will be the main assessment for the Sudbury Alternative. The results of this study will be summarized and included in the Northfield study so that complete assessments of all alternatives appear in the Northfield EIR.

QUESTION: (3) Table 1-1, page 3. Specific citations should be provided for references alluded to under "This information is to be supplied by other reports".

REPLY: This citation has been clarified in the revised technical memorandum, Appendix E.

QUESTION: (4) Table 1-2, page 4. Under "Connecticut River Tributaries" and "Northfield Flood Skimming," what is meant by "conceptual model"? The notion of a conceptual model should be expanded.

REPLY: Please refer to the figure entitled "Conceptual Model of a Systems Approach to an Impact Assessment Process" and the "Recommended Approach" section of the Northfield Flood Skimming Alternative in the technical memorandum report for a discussion of the conceptual model.

QUESTION: (5) Page 5.2. General Introduction. The phrase "flood skimming" should be defined.

REPLY: The term "flood skimming" will be defined by the engineering consultant. See the engineering technical memorandum, Appendix

QUESTION: (11) Page 13, Table 4-1. Some references listed here are not in the Literature Cited" section.

REPLY: Please see corrected and revised "References" section.

QUESTION: (12) Page 17, 5E. Evaluation of Information. Many examples are given in this memo of considering rare and endangered species. Why are only rare and endangered plants and animals considered important? Possible effects on community structures, species composition, patterns of succession, etc., might be considered equally important. (See NCAC Statement on the Issue of Diversion and NCAC's Report on Indicator Species.)

REPLY: The basic information useful in dealing with the ecological concepts of community structure, species composition, etc. is separate from the question of whether rare and endangered species are present on an area. These ecological concepts are indeed important for evaluating impacts of this alternative and will be used in the Phase II assessment. Also, the definition of threatened and endangered species has a legal basis as well as an ecological basis.

QUESTION: (13) Page 19, 6A.2. Description of the Alternative. The statement "replacing the existing vegetation with a non-living cover" should be explained.

REPLY: Maximum water yield increases are achieved when evapotranspiration is minimized. Non-living surfaces such as talus slopes or boulder fields have minimum evapotranspiration rates. In Phase II a wide range of watershed management alternatives will be considered for realistic options. Please see revised text.

QUESTION: (14) Page 22, 6D.3. Rare and Endangered Species. NCAC suggests NER try Bird News of Western Mass. for information on rare and endangered animals in Quabbin.

REPLY: Information from Bird News of Western Mass. will be included in the Phase II assessment.

QUESTION: (15) Page 23, 6E1. Effects of Forest Clearance. NCAC was unaware that anyone had suggested a vegetation management approach that would create a situation of 100% exposed soil. Various scenarios of forest clearance should be discussed and agreed to by MDC, NCAC, WFEM, and NER before the commencement of Phase II.

REPLY: A vegetation management approach that would provide 100% exposed soil has not been suggested for Quabbin Watershed. The statement in question was a general technical assessment of possible effects and should not be interpreted as a suggestion for an implementation policy. Please see revised text in the section on "Description of the Alternative".

QUESTION: (16) Page 24, Table 6-1. Where did the numbers listed for "maximum potential water yield increase from treated areas" come from?

REPLY: The numbers listed for "maximum potential water yield increase" were obtained from estimates made by the watershed expert with New England Research, Inc. The numbers are based on a preliminary assessment of research results cited in the section on "Effects of Forest Clearance". This table was subsequently deleted, however, because the information reported was too preliminary to allow conclusions at this early stage of the study.

QUESTION: (17) Page 28, paragraph 1. Many of these citations are not in the Literature Cited Section or are erroneously listed. For example, there is no such publication as "Sackett and Bower, 1979". What was intended here?

REPLY: The publication in question is "Sackett and Brower, 1979". Upon reinvestigation, it was determined that this publication is not applicable to the discussion of aquatic community composition and has therefore been deleted from the references.

QUESTION: (18) Page 28, paragraph 3. The University of Massachusetts (Amherst) and Harvard are conducting surveys throughout Massachusetts for rare and endangered species.

REPLY: The data from these surveys will be used as they become available. However, the text for this section has been revised.

QUESTION: (19) Page 31, 8A. Introduction. The phrases "skimming water" and "periods of high water flow" must be defined.

REPLY: These terms will be defined by the engineering consultant. Please see engineering technical memorandum, Appendix

QUESTION: (20) Page 31, 8C. Necessary Information. #2. Water quality data should include an assessment of radiocontaminants from Vernon, resulting from spills and regulated release, in water column, biota, or sediment.

REPLY: Water quality data include all classes of parameters. Please see Appendix 10A, Table 2.

QUESTION: (21) Page 34, 8F. Recommended Approach. Would diverted waters, in raising Quabbin's water level, inundate vegetation, thus leading to its decomposition and resultant decline in water quality? (See suggestion 3B.9. of NCAC's <u>Report on Indicator Species</u>, page 18.

REPLY: No. Annual water level fluctuations in the reservoir keep the shoreline essentially free of vegetation up to full pool. It is only during extended periods of drawdown (e.g., several years)that terrestrial vegetation can become established below the full pool elevation if the growth is not controlled. Restoring the reservoir to full pool status each year by diverted waters would inhibit such vegetative growth.

QUESTION: (22) Pages 36-50. References must be properly cited.

REPLY: The list of references has been corrected and is now complete.

QUESTION: (23) Page 63. Acipenser oxyrhynchus is considered "threatened" in Massachusetts (according to D. Smith, Museum of Zoology, U. Mass., Amherst).

REPLY: Please note that no reference is made to threatened species on page 63. On page 73, Attachment #4, which is the list provided by the U.S. Fish and Wildlife Service, does not include the species in question, and neither does the official Commonwealth of Massachusetts 1980 list, Attachment 5 on page 74. However, it is included in Mugford's (1976) list, Attachment 6 on page 75.

NORMANDEAU ASSOCIATES, INC.

NORTHFIELD WATER SUPPLY

ALTERNATIVES STUDY

PHASE I TECHNICAL MEMORANDUM, PRELIMINARY DRAFT

WATER QUALITY AND ECOLOGY - RIVERS, ESTUARIES AND TUNNEL RIGHT-OF-WAYS

Submitted to

WALLACE, FLOYD, ELLENZWEIG, MOORE, INC.

UMMARY

The objectives of the Phase I Investigations were to 1) identify the major water quality, aquatic ecology and terrestrial ecology issues relevant to each alternative, 2) determine the kind of information needed to address the issues, 3) assess the adequacy of the existing data for addressing the issues and 4) recommend methods for filling gaps in the existing data.

Northfield Alternative -- Existing water quality data is not adequate to assess the effects of flood skimming on drinking water standards or aquatic organisms. A sampling program is recommended to characterize water quality during the months when skimming would occur. Samples would be taken above and below Turners Dam, would include commonly accepted water quality indicators as well as parameters known to affect oxygen depletion rates, and would be taken both at night when the pumped storage is in operation and during the day. If a comparison showed significant drawdown-related water quality degradation, computer simulation of flood skimming effects could be undertaken.

The aquatic organisms of the Connecticut River have been recently studied. The Northfield Citizens Advisory Committee (NCAC) has developed a list of indicator species (Table 1-1) each species on the list having been selected on the basis of sound criteria. With the exception of the lamprey, the existing data is adequate to assess the impacts of flood skimming, if interpreted in conjunction with computer simulation of skimming effects on river stage and water quality.

Vegetative communities of the Connecticut River floodplain have been recently studied, and data is adequate to assess flood skimming impacts. Data on bird populations is available only for certain habitats, and data on mammals and herptiles is completely lacking, therefore field studies are recommended to characterize Connecticut River wildlife. Computer simulation of stage effects will be needed to define the lower limit of the study area, and assess impacts. Vegetation and wildlife of the Northfield ROW have been recently studied and data is adequate to assess the impacts of spoil disposal. The Osgood Brook Heron Rookery would have to be precisely located in order to avoid any possible impacts.

Merrimack River Alternative -- Existing water quality data is not adequate to assess flood skimming effects, and a sampling program is recommended to characterize water quality during the months that skimming would occur. Sample design would be the same as that recommended for Northfield. Computer simulation would be undertaken only if such were found to be necessary.

Baseline data on the aquatic organisms of the Merrimack River is inadequate. Sampling is recommended from Tyngsboro to the mouth of the river in order to characterize the resident invertebrate and finfish communities and measure diversity.

TABLE 1-1 CONNECTICUT RIVER INDICATOR SPECIES [1]

Common Name	Scientific Name	Status
Shortnose sturgeon	Acipenser brevirostrum	U.S. Endangered Species List
Atlantic sturgeon	Acipenser oxyrhynchus	Rare Species List for Mass. & Con
American shad	Alosa sapidissima	Consumer Trophic Level; Sport Fi
Carp	Cyprinus carpio	Omnivor Trophic Level
Northern pike	Esox niger	Preditor Trophic Level; Sport Fi
Channel catfish	Ictalurus punctatus	Omnivor Trophic Level; Sport Fish
Sea lamprey	Petromyzon marinus	Preditor Trophic Level; Entrainme
Atlantic salmon	Salmo salar	Consumer Trophic Level; Sport Fi
River mussel	Prolasmidonta heterodon	Under Consideration as Endangere species
Bald eagle	Halioeetus leucocephalus	U.S. Endangered Species List
Osprey	Pandion halioetus	Endangered Species List for Conn.
Peregrine falcon	Falco peregrinus	U.S. Endangered Species List
False loosestrife	Ludwigia polycarpa	Rare Species List for Mass & Conn
Sandbar willow	Salix interior	Rare Species List for Mass. & Con
Arrowhead	Sagittaria cuneata	Rare Species List in Conn.

[1]Taken from Northfield Citizens Advisory Committee Report on Indicator Species (1979)

Once community characteristics are known, a group of indicator species can be selected for assessment of flood-skimming impacts.

Existing information on vegetative and wildlife communities of the Merrimack River floodplain is not adequate to assess the effects of flood skimming. Field studies are recommended to characterize the plant communities and their bird, mammal and herptile populations. Computer simulation of stage effects will be needed to define the lower limit of the study area and assess impacts.

Millers River Alternative -- Existing water quality data is not adequate to assess the effects of flood skimming. Sample design would be the same as that recommended for Northfield. Computer simulation would be undertaken only if such were found to be necessary.

Baseline data on the aquatic organisms of the Millers River is not adequate to assess the impacts of flood skimming, therefore field studies are recommended to characterize resident invertebrate and finfish communities and measure diversity. Indicator species can be selected once community characteristics are known, and flood skimming impacts assessed for these species.

Existing data on the vegetative and wildlife communities of the Millers River floodplain is inadequate, and field studies are recommended to characterize these communities from the diversion point to the confluence with the Connecticut River. Computer simulation of stage effects will be needed to assess impacts. Site-specific data on the vegetative and wildlife communities of the proposed tunnel ROW is lacking, and studies are recommended to provide this data in order to assess the effects of spoil disposal.

Desalinization Alternative -- The existing data base is adequate to assess desalinization impacts and no additional field studies will be recommended if the facility is sited in Plymouth.

Table 1-2 is a summary of the adequacy of existing information for addressing issues and assessing impacts; Tables 1-3 through 1-6 are a synoptic evaluation of information pertaining to each of the issues.

TABLE 1-2 SUMMARY OF ADEQUACY[2] OF EXISTING INFORMATION

		Northfield	Merrimack River	Millers River	Desalinization
Issue:	1. Instantaneous Withdrawal	+	+	+	x
	2. Fluctuating Water Levels	+	+	+	x
	2a. Instantaneous Degradation of Water Quality	*	*	*	x
	2b. River Cleansing Ability	-	-	-	x
	3. Upstream Movement of Saline Water	+	+	x	x
	4. Contaminants in Diverted Water	*	*	*	x
	5. Effect of Desalinization on Hydrology	x	x	x	-
	6. Desalinization Effect on Water Quality	x	x	x	-
	7. Benthos and Finfish	+	-	-	x
	8. Impacts on Indicator Species	+	-	-	x
	9. Impacts on River Mussel	-	x	x	x
	10. Sea Lamprey Diverted to Quabbin	-	x	x	x
	11. Anadromous Fish Homing	-	-	-	x
	12. Impacts on Estuarine Organisms	+	-	x	x
	13. Impacts on Salmon and Shad	+	+	+	x
	14. Revegetation and Erosion Control	+	+	+	x
	15. Impacts on Floodplain Succession	+	-	-	x
	16. Invasion of Agricultural Land by Weeds	*	x	x	x
	17. Impacts on Fertility of Agricultural Land	*	x	x	x
	18. Impacts on Floodplain Wildlife	*	-	-	x
	19. Impacts on Waterfowl Breeding	+	+	+	x
	20. Impacts on Wetlands	+	+	+	x
	21. Salt Wedge Movement Effects on Plants	+	-	x	x
	22. Impacts on Rare and Endangered Species	+	-	-	x
	23. Impacts on State Managed Lands	+	+	+	x
	24. Impacts of ROW Spoil Piles	+	x	*	x
	25. Desalinization Effect on Marine Organisms	x	x	x	+
	26. Impacts of Disposing of Saline Solution	x	x	x	+

+ Adequate
* Partially Adequate
- Inadequate
x Not Appropriate
[2] Assessments of adequacy of data were based on the professional judgements of the investigators.

TABLE 1-3. ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Water Quantity and Quality

	Issues	Necessary Information	Status of Existing Information
1-	Proportion of stream flow instantaneously withdrawn, especially at lowest flow allowed (Connecticut, Millers & Merrimack River options)	Pumping rates; inflow/outflow data from gauging stations.	Historical gauged flow data adequate; resolution depends on specification of pumping rates.
2-	Effect of flood skimming on fluctuations in water levels (artificial tides). (Connecticut, Millers & Merrimack Rivers) if incremental change appears measurable (not negligible) consider 2a&b otherwise skip to 3	Existing water level fluctuations and water volumes in withdrawal reservoirs, especially during lowest flows at which diversion is allowed.	Historical data adequate; resolution depends on specification of minimum permissible flows for skimming from Merrimack and Millers Rivers.
2A-	Instantaneous water quality impact below intake point (Connecticut, Millers & Merrimack Rivers).	Sources and sinks of water quality constituents of interest (e.g., Temperature, BOD, DO, pH, coliform bacteria, suspended solids, conductivity, plant nutrients); mass balance loadings as appropriate; time of travel for withdrawal "plug"; decay/reaction rates.	Available data important as background; specific need for data from early morning hours as pumped storage withdrawals occur then. Computer simulation being considered.
2B-	Effect of flood skimming on river cleansing ability (Connecticut, Millers & Merrimack Rivers).	River sediment grain-size composition; mass movement of bed load; rate of attenuation of withdrawal "plug"; maximum instantaneous proportion of flow reduction at upper most tidal reach.	Grain-size composition data spotty (fair overall); mass movement of suspended solids only (no possibility of short-term acquisition of total bed load data). Computer simulation may be needed to project hydraulic impacts (assessments to be based on hydraulics due to lack of actual bedload data).
3-	Effect of flood skimming on upstream movement of saline waters (Connecticut & Merrimack Rivers).	Threshold fresh water down stream flows sufficient to prevent turn-of-tide on Connecticut River; review of salinity intrusion model (NAI, 1971) on Merrimack River.	Existing information is adequate to address this issue on Connecticut River; resolution on Merrimack River depends on specification of pumping rates and minimum permissible withdrawal flows,

TABLE 1-3 (Continued)

	Issues	Necessary Information	Status of Existing Information
4-	Contaminants present in skimmed water (non-compliance with drinking water standards) (Connecticut, Millers & Merrimack Rivers)	Results of recent chemical analyses, especially: trace metals, PCB's, pesticides and radioactive substances.	Available data important as background; specific need for sampling of hig er frequency during freshet.
5-	Hydrological impact (desalinization option)	Plant pumping capacity	Specifications needed
6-	Donor/receiving water quality degradation (desalinization)	Plant size and location; effluent discharge characteristics	Comparative data probably adequate; issue resolution depends on development of engineering design criteria.

TABLE 1-4 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Ecology, Rivers, Tributaries and Estuaries

	Issues	Necessary Information	Status of Existing Information
7-	Will flood skimming affect benthic and finfish communities (Merrimack, Millers & Connecticut Rivers)	Species composition and distribution of aquatic organisms; effects of skimming on river stage, and water quality, temperature.	Existing information on aquatic communities is adequate for the Connecticut River; Merrimack & Millers River data needed; skimming impact to be assessed.
8-	Effect of flood skimming on indicator species (Connecticut River)	Life history information for eight species; effect of skimming on river stage, temperature and water quality.	Existing life history information is adequate; skimming impact to be assessed.
9-	Effect of flood skimming on river mussel Prolasmidonta heterodon), proposed endangered mollusc. (Connecticut River)	Effect of skimming on river stage and water quality.	Live river mussels have been recently collected at Windsor Locks, Conn.; causes of habitat destruction have been suggested; skimming impact on river stage to be assessed.
10-	Will flood skimming cause sea lamprey entrainment and diversion to Quabbin. (Connecticut River)	Establish presence of lamprey in Turners Pool; effect of skimming on downrunning lamprey.	Data doesn't exist; expect data on lamprey passed at Turners Dam during spring 1980 to be available summer 1980.
11-	Will the loss of freshet affect anadromous fish homing abilities (Merrimack, Millers & Connecticut Rivers)	Effect of skimming on river discharge in the estuary.	Impact of alternatives to be assessed.
12-	Will flood skimming affect distribution of estuarine organisms (Merrimack & Connecticut Rivers).	Species composition of estuarine area; effect of possible changes in salt wedge distribution due to reduced freshwater flows.	Aquatic organisms of lower Connecticut River and estuary are known; data needed for Merrimack River; skimming impact to be assessed.
13-	Skimming effect on river migration of Atlantic salmon and American shad at intake point. (Merrimack, Millers & Connecticut Rivers)	Effect of water withdrawal on adult and juvenile migrations; proportion of river flow to be skimmed.	Effect of water withdrawal on migratory movements of these two fish adequate; percentage of river flow skimmed to be estimated.

TABLE 1-5 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Ecology, Floodplains and Tunnel ROW's

	Issues	Necessary Information	Status of Existing Information
14-	Effects of flood skimming on revegetation and erosion control along the river. (Connecticut, Millers & Merrimack Rivers)	Effects of skimming on erosion rate; mechanisms of erosion; effect of tidal action on establishment of vegetation; artificial revegetation.	Existing information is adequate to address the issue.
15-	How and where would reduced flooding effect succession on the floodplain. (Connecticut, Millers & Merrimack Rivers)	Species composition, seral stages, successional patterns, and distribution of floodplain communities; effects of skimming on river stage.	Plant community information is adequate for the Connecticut; data inadequate for Millers & Merrimack; distributions available for all; skimming impact on stage to be assessed.
16-	Will alien plants adapted to dryer soil invade agricultural fields (Connecticut River)	Species composition and structure of fields in progressive stages of abandonment along a moisture gradient in the floodplain.	Existing information is partly adequate to addres the issue.
17-	Effects of reduced flooding on fertility of agricultural land in western Massachusetts and Connecticut (Connecticut River)	Soil nutrient data for fields in progressive stages of abandonment along a moisture gradient in the floodplain.	Existing information is partly adequate to addres the issue.
18-	Effects of reduced flooding on wildlife activities and habitats on the floodplain (Connecticut and Merrimack Rivers)	Species composition seral stages, successional patterns, and distribution of floodplain communities; effects of skimming on river stage; wildlife inventory data, habitat requirements.	Plant community and bird inventory data are adequa for the Connecticut, but mammal and herptile data are needed; plant and wil life data inadequate for Millers and Merrimack; distributions available fo all; skimming impact to be assessed.
19-	Effect of increased tidal amplitude on waterfowl breeding behavior. (Connecticut, Millers and Merrimack Rivers)	Waterfowl species which regularly breed in floodplain communities of each river and their requirements with respect to water level.	Existing information is adequate to address the issue.

TABLE 1-5 (Continued)

	Issues	Necessary Information	Status of Existing Information
20-	Wetlands alterations under Massachusetts and Connecticut wetlands protection acts (Connecticut, Millers and Merrimack Rivers)	Interpretation of laws as to jurisdiction in terms of habitats affected, and wetland functional values; inventory of floodplain, river and ROW wetland types; functional values of wetland types; effects of skimming on river stage.	Wetland statutes, inventories, and information pertaining to functional values are available for all three rivers and tunnel ROW's; skimming impact to be assessed.
21-	Effects of possible changes in the distribution of the salt wedge due to reduced freshwater flows on plant communities. (Connecticut and Merrimack Rivers)	Species composition, seral stages, successional patterns, and distribution of lower floodplain communities; effects of skimming on freshwater flow to the lower river.	Plant community data are adequate for the lower Connecticut; data inadequate for the Merrimack; distributions available for both; skimming impact to be assessed.
22-	Effects on rare and endangered plants and wildlife. (Connecticut, Millers and Merrimack Rivers).	Records of occurrence of r&e plant species; active breeding or nesting sites, overwintering or migratory stopover areas, habitat requirements; effects of skimming on river stage; location and size of spoil piles.	Existing information is adequate to address the issue; skimming impact to be assessed.
23-	Effects of flood skimming and ROW spoil piles on conservation lands and wildlife management areas (Connecticut, Millers and Merrimack Rivers).	Locations of wildlife management areas, species managed; locations of town owned conservation lands; effects of skimming on river stage; location and size of spoil piles.	This information will be obtained from existing sources; skimming impact to be assessed.
24-	Effects of ROW spoil piles on representative species in each habitat and on their habitats (Connecticut and Millers options).	Species composition and distribution of upland vegetative communities; wildlife inventory data, habitat requirements; location and size of spoil piles.	Existing information is adequate to address the issue.

TABLE 1-6 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Ecology, Coastlines

	Issues	Necessary Information	Status of Existing Informatic
25-	Entrainment and impingement of macroinvertebrates, ichthyoplankton and larvae in the plant intake system.	Inventory data for macroinvertebrates and fish of near coastal waters in the vicinity of the proposed site; plant specifications including pumping rates, hours of operation, etc.	Inventory data are adequate to address the issue if facilit is sited in Plymouth plant specifications needed.
26-	Disposal of concentrated saline solution.	Plant specifications including unit time volume and concentration of solution.	Plant specifications needed.

INTRODUCTION

This report presents the findings and conclusions of Phase I of the Northfield-Water Supply Alternatives Study. Normandeau Associates, Inc. (NAI) areas of responsibility in Phase I investigations include the water quality, aquatic ecology and terrestrial ecology of four of the nine alternatives. The four alternatives are the Connecticut River, Millers River, the Merrimack River and a coastal desalinization site. The study area for the Connecticut River has been defined as the segment from Vernon Dam, near the Massachusetts-Vermont line, to its mouth; that for the Merrimack includes the segment from Tyngsboro to its mouth; and that for the Millers River includes the segment from the intake to its mouth.

Major issues relevant to each area of responsibility that must be addressed to assess the impacts of the four alternatives have been identified. The relationship between issues and alternatives is shown in matrix form in Table 1-2. The kind of information necessary to address each issue and its adequacy with respect to impact assessment have been determined. Issues, necessary information, and status of existing information are summarized in the tables accompanying each group of issues. Gaps in the existing information have been identified and methodologies for filling the gaps are recommended (see recommendations).

METHODS

Major issues were identified from a review of correspondence and memoranda from the Northfield Citizens Advisory Committee (NCAC), from proceedings of conferences on the Northfield Project, and in dialogues with various agencies and individuals. Since the primary objective of Phase I investigations was to assess the status of the existing information, references and data were abstracted, but in most cases not studied in detail. As the importance of each issue becomes better defined later in the study, the data can be obtained as needs warrant.

Information sources throughout Massachusetts, Connecticut, and southern New Hampshire were contacted. In Boston, literature was reviewed and knowledgeable individuals interviewed in offices of various state and federal agencies such as the Metropolitan District Commission (MDC), New England River Basins Commission (NERBC) and the Environmental Protection Agency (EPA). In the Connecticut Valley, files of published and unpublished information at the office of NCAC were reviewed. Libraries, professors, graduate students, and various agencies in the five college area were also researched or interviewed. A complete listing of all agencies and individuals contacted and literature reviewed is presented at the end of this report.

EVALUATION OF EXISTING DATA

Water Quality: General Status of Existing Information

Water quality information on the Connecticut, Merrimack and Millers Rivers is abundant, most of it having accumulated in the past decade. One of the most authoritative sources is the U. S. Geological Survey, Water Resources Division (USGS) which publishes yearly Water Resources Data summaries covering almost every pertinent aspect of water quality. Stream flow data are reported as daily mean values and water quality data derive from grab samples taken approximately monthly. Stream gauging stations are usually not at the same site as water quality monitoring stations (one exception is the national stream-quality accounting network and radiochemical station at Thompsonville, Connecticut, immediately upstream from Enfield Dam). The principal drawback to sole reliance on the data set generated by the USGS monitoring program (also available as multiple station listings from USGS' "WATSTORE" computer data base) is that stations are few and often far between. On the Connecticut River, from the Massachusetts border with Vermont and New Hampshire to the river mouth on Long Island Sound, (a 137-mile stretch) the USGS maintains eight water quality monitoring stations, the closest of which is approximately six miles above the Northfield pumped storage tailrace (the next is 43 miles downstream at Holyoke Dam).

In contrast, water quality data collected by the Massachusetts Division of Water Pollution Control (MDWPC) derive from approximately 31 sampling points on the Connecticut River, covering a 68.7 mile stretch (MDWPC, 1978). On the Merrimack River mainstem in Massachusetts, the USGS maintains two water quality monitoring stations while the MDWPC has occupied approximately eighteen stations (MDWPC, 1974). Surveys by the MDWPC are typically confined to the summer months and have occurred only in certain years (Connecticut, 1966, 1971/73, 1978; Merrimack, 1974, 1979). In conjunction with mainstem surveys, and as separate survey programs, the MDWPC has also sampled major tributary streams (e.g., the Deerfield in 1965, 1973 and 1977; the Millers River in 1965, 1973, 1979 and 1980).

In the spring of 1978 the MDWPC conducted an extensive sampling effort throughout the Connecticut River watershed, involving approximately 64 minor tributaries and drainage from 13 landfill sites. In support of a mathematical water quality model these data would be valuable for estimating contributions from non-point sources of pollution. Major point sources of pollution to the Connecticut River have also been inventoried (MDWPC, 1976, 1977, 1978).

The MDWPC water quality data set is less comprehensive than the USGS data set in that pesticides, conductivity, phenols, and PCB's are not monitored. Radioactivity measurements are made monthly by the Massachusetts Department of Public Health, Lawrence Experiment Station at four Connecticut River sites (Northfield, Holyoke, Springfield, and Agawam), and one on the Deerfield River. The MDWPC monitors bio-

chemical oxygen demand (BOD) while the USGS measures chemical oxygen demand. Although the two parameters are related, the relationship varies with pollutant composition and, thus is far from consistent.

A third water quality data set has been provided by New England Research Inc. (NER) under contract to the MDC. For six of the past eight years, NER monitored monthly a wide range of water quality characteristics and constituents, approaching in comprehensiveness the USGS monitoring program. However, the NER monitoring network is oriented toward the MDC reservoir system; only one sampling station (immediately above the tailrace entry of the pumped storage) is on the Connecticut River mainstem.

Aquatec, Inc. has conducted quarterly surveys for trace metals, plant nutrients, BOD, solids, and such traditional limnological analyses as pH, alkalinity and hardness, at Vernon, Vermont, approximately thirteen miles above the Northfield pumped storage tailrace. Automated samplers at the Vermont Yankee Nuclear Station also record DO, conductivity, turbidity, pH and temperature year round. The immediate importance of the Aquatec data to the Northfield option is somewhat decreased by the fact that inflows from the Ashuelot River (an industrial and municipal waste receiving river) and Northfield Sewage Treatment Plant enter downstream from the sampling points.

Northfield Alternative -- Although water quality information is abundant, it is uncertain whether existing data taken during the day, approximately monthly and typically confined to summer, is sufficient to assess the instantaneous water quality impacts of flood skimming. A sampling program should be undertaken to characterize the daily and weekly river dynamics during spring freshet months, when skimming would occur, by sampling for a series of consecutive days out of each week for several weeks. Sampling should include commonly accepted water quality indicators (e.g., fecal coliform counts, pH, total phosphorus, nitrate nitrogen, turbidity, and total solids), and also constituents and characteristics which are known to affect oxygen depletion rates (e.g. BOD, temperature, flow rate, time-of-travel, and reduced forms of nitrogen). Sampling should occur at a control point above Turners Pool, at the diversion point, in Turners Pool, and in the section below the dam, during the hours when river water is being pumped to Northfield Mountain Reservoir, and during the daytime to compare water quality conditions in the absence of drawdown. If the comparison showed significant drawdown-related water quality degradation, computer simulation of flood skimming impact should be undertaken.

Merrimack River Alternative -- For the reasons discussed in the Northfield Alternative, a sampling program is recommended to characterize river dynamics during the freshet months Sample design would be similar, with a sample station at a control point above the intake, a station at the intake and one below. Computer simulation would be undertaken only if such were found to be necessary.

Millers River Alternative - For the reasons discussed in the Northfield Alternative, a sampling program is recommended to characterize river dynamics during the freshet months. Sample design, timing and sample station locations would be the same as recommended for the Merrimack River Alternative. Computer simulation would be undertaken only is such were found to be necessary.

Desalinization Alternative -- Water quality considerations do not apply here.

Water Quality: Discussion of Issues

For convenience, a synoptic evaluation of information pertaining to water quality related issues is included (Table 1-3). The following discussion expands on the synopsis.

1 - Issue: Proportional Instantaneous Withdrawal -- Instantaneous drawdown of a donor stream during flood skimming is obviously a larger proportion of instantaneous stream flow than drawdown, averaged over a 24-hour period, is to daily mean flow. To evaluate acute hydrological impact, the relationship between instantaneous stream flow and instantaneous pumping rate must be known. The critical relationship is assumed to be between pumping rate and the lowest flow at which diversion will be allowed. For the Northfield flood skimming of the Connecticut River, a statutory limit of 17,000 cfs, measured at the USGS Montaque stream gauge, has been established (presumably the gauge is checked every 30 minutes while skimming is proceeding). The Falls and Deerfield Rivers contribute to stream flow at the Montaque gauge but not to withdrawal at the Northfield tailrace (upstream flow is blocked by Turners Falls Dam); therefore, actual donor stream flow is less than 17,000 cfs by the amount contributed by the two rivers. Normal operating capacity of the pumps at the Northfield project is known, so reasonably accurate estimates of proportional withdrawal can be made using available USGS hydrologic data. The same can be said of the Merrimack and Millers Rivers once pumping rates and minimum stream flows have been studied and proposed.

TABLE 1-3 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Water Quantity and Quality

	Issues	Necessary Information	Status of Existing Information
1-	Proportion of stream flow instantaneously withdrawn, especially at lowest flow allowed (Connecticut, Millers & Merrimack River options)	Pumping rates; inflow/outflow data from gauging stations.	Historical gauged flow data adequate; resolution depends on specification of pumping rates.
2-	Effect of flood skimming on fluctuations in water levels (artificial tides). (Connecticut, Millers & Merrimack Rivers) if incremental change appears measurable (not negligible) consider 2a&b otherwise skip to 3	Existing water level fluctuations and water volumes in withdrawal reservoirs, especially during lowest flows at which diversion is allowed.	Historical data adequate; resolution depends on specification of minimum permissible flows for skimming from Merrimack and Millers Rivers.
2A-	Instantaneous water quality impact below intake point (Connecticut, Millers & Merrimack Rivers).	Sources and sinks of water quality constituents of interest (e.g., Temperature, BOD, DO, pH, coliform bacteria, suspended solids, conductivity, plant nutrients); mass balance loadings as appropriate; time of travel for withdrawal "plug"; decay/reaction rates.	Available data important as background; specific need for data from early morning hours as pumped storage withdrawals occur then. Computer simulation being considered.
2B-	Effect of flood skimming on river cleansing ability (Connecticut, Millers & Merrimack Rivers).	River sediment grain-size composition; mass movement of bed load; rate of attenuation of withdrawal "plug"; maximum instantaneous proportion of flow reduction at upper most tidal reach.	Grain-size composition data spotty (fair overall); mass movement of suspended solids only (no possibility of short-term acquisition of total bed load data). Computer simulation may be needed to project hydraulic impacts (assessments to be based on hydraulics due to lack of actual bedload data).
3-	Effect of flood skimming on upstream movement of saline waters (Connecticut & Merrimack Rivers).	Threshold fresh water down stream flows sufficient to prevent turn-of-tide on Connecticut River; review of salinity intrusion model (NAI, 1971) on Merrimack River.	Existing information is adequate to address this issue on Connecticut River; resolution on Merrimack River depends on specification of pumping rates and minimum permissible withdrawal flows,

TABLE 1-3 (Continued)

	Issues	Necessary Information	Status of Existing Information
4-	Contaminants present in skimmed water (non-compliance with drinking water standards) (Connecticut, Millers & Merrimack Rivers)	Results of recent chemical analyses, especially: trace metals, PCB's, pesticides and radioactive substances.	Available data important as background; specific need for sampling of higher frequency during freshet.
5-	Hydrological impact (desalinization option)	Plant pumping capacity	Specifications needed
6-	Donor/receiving water quality degradation (desalinization)	Plant size and location; effluent discharge characteristics	Comparative data probably adequate; issue resolution depends on development of engineering design criteria.

2 - Issue: Fluctuating Water Levels -- Operation of hydropower dams on the Connecticut River creates artificial tides which can be erratic but usually have a diurnal and weekly component, related to peaks in electric power demand. Hydrological data are available (C. Wiener, U. S. Army Corps of Engineers, New England Division, Personal communication; Western Massachusetts Electric Company, 1973) from which to project changes in tidal characteristics which may result from skimming Connecticut and Millers River water. Similar hydrologic information has been compiled for the Merrimack River in connection with a water quality model (NAI, 1975) but before predictions of tidal fluctuations can be made, a pumping and minimum flow regimen would have to be specified.

2A - Issue: Water Quality Degradation -- Simple mass balance calculations were made using USGS data for total phosphorus, a conservative element. Mass balance is simply the concentration of a chemical element in water times flow, generally expressed as pounds per day loading. These data indicate that on a 24-hour basis, under worse-case loading conditions, the water quality impact on downstream reaches of the Connecticut River due to flood skimming at Northfield, would be negligible. These same calculations, however, give uncertain predictions concerning the magnitude of water quality impact during and immediately following a drawdown event. Drawdown events presently occur on the Connecticut River in connection with pumped storage withdrawals, but since the events normally occur in the early morning hours (i.e., before 6:00 a.m. on weekdays, before noon on Sundays) it is uncertain whether existing data sets, taken between 7:00 a.m. and 8:00 p.m. on weekdays, adequately address the issue of instantaneous impact. Backed up by valid mathematical modeling techniques, a water quality sampling program, oriented around early morning pumped storage withdrawal events, would be useful in evaluating the risk of significant downstream water quality degradation resulting from skimming for water supply.

2B - Issue: River Cleansing -- Rivers carry a sediment load consisting largely of material eroded from the stream banks plus material of similar origin contributed by tributary streams. Particularly in wet weather, a substantial portion of the suspended solids load may be solids emanating from storm drains, combined sewer overflows, and wastewater treatment plant outfalls. The flushing action (tractive force) of moving water keeps these materials from accumulating in the stream bed. Potential problems develop, however, where impoundments (i.e. dams and high slack water in tidal reaches) interrupt the flow. The most serious problem concerns finer-grained materials (silts and clays) as these readily adsorb organic contaminants and trace metals (James and MacNaughton, 1977). Notwithstanding the toxicity of specific contaminants, accumulation of fine-grain particles

with a high organic content can be a source of substantial benthal oxygen demand.

River bed grain-size composition is a reasonably good indication of whether or not fine-grained material is accumulating. Grain-size composition data are available for most relevant stretches of the Connecticut River (Armour, 1966; Fay and Downer, 1973; Brigham and Jonash, 1972; G. Horne, 1980). More directly applicable to evaluating impact of water supply skimming, however, would be data equating stream flow and the river's ability to keep the stream bed clear of fine particulates. Collection and interpretation of such data requires long-term study such as is currently being conducted by the Department of Earth and Environmenta Sciences of Wesleyan University. Very little of the prelin inary results of this study will be available before the er of 1980 (G. Horne, 1980).

Meanwhile, an expedient substitute approach will have to be taken, for example, assumption of a theoretical mathematica relationship between flow, river channel geometry, and stream bed cleansing capacity. The analysis should focus c the lowest flows at which water supply diversions would be allowed (see also first issue) and consider specifically th risk of impairing the river's capacity to resuspend fine particulates from the stream bottom.

Tidal portions of both the Connecticut and Merrimack Rivers may present special analytical problems as flow may be stopped or reversed when the tide runs in the upstream (flood) direction. In the Connecticut River flow reversal is prevented by flow characteristics of spring runoff condi tions. In the Merrimack River flow reversal may occur up t Essex Dam. The relationship between flows which prevent turning of the tide and flows from which water may be skim can be explored using available historical data.

3 - Issue: <u>Upstream Movement of Salinity</u> -- Only a portion of the tidal reaches on the Connecticut and Merrimack Rivers have high salinity. Typically, with each turn of the tide, a "salt front" (interface between water of low salinity and high salinity) moves up and down a relatively short stretch of river nearest the mouth. On both rivers, available data (USGS, 1976; NAI, 1971) are adequate to evaluate the relationship between upstream migration of high salinity water and stream flow. To assess flood skimming impact on the Merrimack River, however, withdrawal rates and minimum allowable stream flows for flood skimming must be specified and a model developed to determine if stage effects extend to the upriver limit of the estuary.

4 - Issue: <u>Donor Stream Compliance with Water Supply Standard</u> The Connecticut, Merrimack and Millers Rivers receive larg quantities of industrial and municipal wastes (see especia

MDWPC, 1976, 1977, 1978). The USGS water quality sampling stations at Northfield and Lowell, Massachusetts are well situated to evaluate the kinds and quantities of contaminants likely to be introduced into public water supplies if flood skimming for such purposes were permitted. On the Connecticut River the NER sampling point is immediately above the proposed intake point, and therefore more than five miles closer than the USGS Northfield sampling point. Criteria for evaluating standards compliance are contained in USEPA (1976) and the US Code of Federal Regulations 40CFR141 (interim primary drinking water rules) and 40CFR143 (secondary drinking water rules).

An unresolved issue, relating to carry-over of contaminants into drinking water supply systems, involves the potential for adsorbtion of trace metals and toxic organics onto fine-grained sediments small enough to be resuspended during freshet conditions but large enough to escape conventional water quality samples. If differences in water chemistry between donor and recipient systems were great enough, potentially harmful trace substances could be remobilized, or desorbed, into the recipient water column. Dr. R. F. Yuretich of the University of Massachusetts Geology Department is interested in further investigating the significance of what is presently only a hypothetical problem on the Connecticut River.

5 - Issue: Desalinization Hydrological Impact -- Seawater is usually considered inexhaustible, however, local hydrological impacts (e.g. artificially induced current patterns) could be ecologically important. To evaluate local hydrological impact, the relationship between natural circulation patterns and plant capacity must be known.

6 - Issue: Desalination Water Quality Impact -- The effluent from a proposed desalinization plant can be presumed to resemble discharges from existing desalination plants of similar design. Information is needed, then, on the size and type of plant which is most likely to meet MDC water supply needs.

Ecology, Rivers, Tributaries and Estuaries: General Considerations

Organisms in a lotic environment can be affected by flood skimming in two major ways: entrainment and impingement at the withdrawal site, and habitat changes caused by reduced flow below the withdrawal site which can in turn affect community structure and diversity. The effects of flood skimming on aquatic life are related to the instantaneous effects of a skimming event on river physical and chemical characteristics such as stage and concentrations of chemical elements. Computer simulation of flood skimming effects on

river stage is needed for all river alternatives in order to predict effects on species such as northern pike (Esox lucius) which attach their eggs to shallowly submerged floodplain vegetation and river mussels. Computer simulation of flood skimming effects on water chemical parameters would also be needed for the Northfield alternative if results of field surveys in the Connecticut River showed significant pumped-storage-related water quality degradation. The need for computer simulation of chemical parameters for the Merrimack and Millers River will also depend partly upon the results of field sampling. The effects of changes in chemical concentrations on aquatic organisms can then be determined by comparing the data to known tolerance thresholds and life cycle requirements of resident and indicator species.

Northfield Alternative -- The finfish and invertebrate communities of Turners Pool, Northfield Reservoir, Holyoke Pool and the Lower Connecticut River have been recently studied. The NCAC has developed a list of indicator species, each species on the list having been selected on the basis of sound criteria (Table 1-1). Assessment of the effects of flood skimming on these organisms requires life history information pertaining to habitat requirements and water quality criteria. For the finfish species, the existing data is adequate to assess flood skimming effects.

Merrimack Alternative -- Baseline data on the invertebrate and finfish communities is not adequate to assess the impacts of flood skimming, the most recent information being more than 10 years old. It is recommended that sampling be conducted at five sites on the Merrimack River, from the mouth to Tyngsboro, at the stations previously surveyed by Massachusetts Division of Fish and Game. The objective of this sampling would be to characterize the resident invertebrate and finfish communities and measure diversity. Once community characteristics are known a group of indicator species can be selected for assessment of flood-skimming impacts. This group will include representatives of different trophic levels (herbivores, omnivores and carnivores), rare and endangered species, and species of special concern such as Atlantic salmon and American shad.

Millers River Alternative -- Baseline data on the invertebrate and finfish communities is not adequate to assess the impacts of flood skimming, the most recent information being ten years old and taken under different water quality conditions than exist presently. Sampling should be conducted at stations previously surveyed by Massachusetts Division of Fish and Game in order to characterize resident invertebrate and finfish communities and measure diversity. Indicator species can be selected once community characteristics are known.

Desalinization Alternative -- Considerations pertaining to riverine and estuarine ecology do not apply here.

Ecology, Rivers, Tributaries and Estuaries: Discussion of Issues

A synoptic evaluation of information pertaining to riverine and estuarine ecology related issues is presented in Table 1-4.

7 - Issue: Impact of Flood Skimming on Benthic and Finfish Communities -- Flood skimming may affect aquatic communities at the intake site by entrainment and/or impingement at the pump. Entrainment and impingement rates are directly related to intake velocities (Boreman, 1977). Intake velocities at the Northfield Mountain Pumped Storage intake are not expected to change, however water will be skimmed for longer periods of time which could affect total impingement and entrainment. Intake velocity and location of the withdrawal site have not been established for the Merrimack River.

The ecology of the Connecticut River has been recently studied and the existing information is adequate to address this issue. Resident fish species and their relative abundance, and invertebrate communities of Turners pool, Northfield Reservoir (Brigham and Jonash 1972, 1973, 1974; Jonash and Schapus 1976; Aquatec, Inc. 1977), Holyoke pool Leonard, 1968), and the Lower Connecticut River (Marcy 1976a, 1976b; Massengill, 1976) have been determined. Fish and benthic studies have also been conducted on the Deerfield and Millers Rivers (Godfrey, 1970; Oatis, 1970). Resident finfish and benthic data on the Massachusetts portion of the Merrimack River are limited (Jerome et al., 1965; Oldaker, 1966; Oatis and Bridges, 1969), and more recent information is needed. An understanding of the effect of flood skimming on river stage and water quality is also needed to assess impacts to the aquatic community.

8 - Issue: Effect of Flood Skimming on Connecticut River Indicator Species -- The NCAC selected eight fish species and several groups of benthic macroinvertebrates as indicator species based on a review of available literature (Sackett, 1979). These include the sea lamprey, shortnose sturgeon, Atlantic sturgeon, American shad, Atlantic salmon, northern pike, carp and channel catfish. Assessment of impacts of flood skimming on these organisms requires life history information especially habitat requirements and water quality criteria. For the finfish species this kind of information is available (Scott and Crossman, 1973; Taubert, 1980; Clayton et al., 1978; Carlander, 1969; Muranski and Pachico, 1977; Gilmore, 1975; Katz, 1972; Levesque, 1970; Marcy, 1976c; Schmitt, 1971; Decola, 1970; Hassler, 1970). Connecticut River benthic assemblages have been

TABLE 1-4 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Ecology, Rivers, Tributaries and Estuaries

	Issues	Necessary Information	Status of Existing Information
7-	Will flood skimming affect benthic and finfish communities (Merrimack, Millers & Connecticut Rivers)	Species composition and distribution of aquatic organisms; effects of skimming on river stage, and water quality, temperature.	Existing information on aquatic communities is adequate for the Connecticut River; Merrimack & Millers River data needed; skimming impact to be assessed.
8-	Effect of flood skimming on indicator species (Connecticut River)	Life history information for eight species; effect of skimming on river stage, temperature and water quality.	Existing life history information is adequate; skimming impact to be assessed.
9-	Effect of flood skimming on river mussel Prolasmidonta heterodon), proposed endangered mollusc. (Connecticut River)	Effect of skimming on river stage and water quality.	Live river mussels have been recently collected at Windsor Locks, Conn.; causes of habitat destruction have been suggested; skimming impact on river stage to be assessed.
10-	Will flood skimming cause sea lamprey entrainment and diversion to Quabbin. (Connecticut River)	Establish presence of lamprey in Turners Pool; effect of skimming on downrunning lamprey.	Data doesn't exist; expect data on lamprey passed at Turners Dam during spring 1980 to be available summer 1980.
11-	Will the loss of freshet affect anadromous fish homing abilities (Merrimack, Millers & Connecticut Rivers)	Effect of skimming on river discharge in the estuary.	Impact of alternatives to be assessed.
12-	Will flood skimming affect distribution of estuarine organisms (Merrimack & Connecticut Rivers).	Species composition of estuarine area; effect of possible changes in salt wedge distribution due to reduced freshwater flows.	Aquatic organisms of lower Connecticut River and estuary are known; data needed for Merrimack River; skimming impact to be assessed.
13-	Skimming effect on river migration of Atlantic salmon and American shad at intake point. (Merrimack, Millers & Connecticut Rivers)	Effect of water withdrawal on adult and juvenile migrations; proportion of river flow to be skimmed.	Effect of water withdrawal on migratory movements of these two fish adequate; percentage of river flow skimmed to be estimated.

studied by the Massachusetts Division of Fisheries and Wildlife (Brigham and Jonash, 1972, 1973, 1974; Jonash and Shapiro, 1976; Massengil, 1976; and Aquatec, Inc. 1977). Information pertaining to the effect of the flood skimming on water quality and river stage however, is also needed but not currently available.

9 - Issue: Effect of Flood Skimming on Homing Ability of Anadromous Fish, Particularly Atlantic Salmon and American Shad -- The American shad is one of the most abundant anadromous fish in the Connecticut River. In 1979 255,753 shad were passed at the Holyoke dam (Covey, personal communication to Mygatt, 1979). American shad are also being restored to the Merrimack River (Wightman and Hendl, 1971). Restoration of the Atlantic salmon runs in the Connecticut and Merrimack Rivers is underway (Anonymous, 1971; Stolte, 1979).

McCann and McGrath (1973) using a 3.8% diversion of Connecticut River flood waters and a flow control of 15,000 cfs at Montague City concluded there would be no serious problems triggering Atlantic salmon and American shad migrations.

River flow requirements for Merrimack River anadromous fish were determined by Cortell and Associates (1974). During April, 6,000 cfs would allow salmon runs to start, while 3,500 cfs in May would provide adequate flow for downriver migrations. Skimming rates and control flows have yet to be determined for the Merrimack River.

10 - Issue: Effectof Flood Skimming on Atlantic Salmon and American Shad -- The effects of pumping water to Northfield reservoir on migrating adult and juvenile shad and emigrating Atlantic salmon smolts have been studied by Layzer (1978a, b) and Layzer and O'Leary (1978). These studies indicated that pumped storage effects on adult and juvenile shad movements were minimal. Atlantic salmon smolts were entrained during the pumping cycle. No abnormal smolt behavior was noticed during the generating cycle. Entrainment was significant (13%) when 10% of river flow was diverted, indicating that entrainment is apparently related to percentage of river flow diverted. Although similar information for the Merrimack and Millers Rivers is not available, the Connecticut River findings are applicable.

Flood skimming may cause increases in water temperature downriver. This could affect upstream movements of American shad. Scherer (1974) found water temperature affected the number of fish passed at the Holyoke dam. Water temperature also affects spawning time and location (Watson, 1968; Marcy, 1972). Skimming effects on water temperature must

be determined before impact to salmon and shad can be assessed.

11 - Issue: Will Flood Skimming Cause Sea Lamprey Entrainment and Transfer to Quabbin Reservoir -- Sea lamprey may be entrained at the pumping facility. Until this year, migration of anadromous species above Turners Fall was blocked by Turners Dam. A new fish lift will be operating during spring 1980, (John O'Leary, 1980) and several fish species, including lamprey will be returned to this river stretch. Lamprey migrations (to spawning areas of moderate current, 15-24 inches of water and a sand gravel, rubble bottom) begins as water warms to 4°C (Scott and Crossman, 1973). Adhesive eggs are deposited in nests constructed by the male. Adults die shortly after spawning. After hatching, ammocetes (juvenile stage of lampreys) burrow out of the nest, drift downstream to sandy-silt and mud areas and burrow in. During the ammocete period, feeding is by filtration. Adults do not feed during migration. Transformation to the adult phase begins between mid July and September and takes two to seven months to complete (Bigelow and Schroeder, 1953; Scott and Crossman, 1973). The ammocete period can be as long as seven years and duration is probably an age-length relationship (Scott and Crossman, 1973). The parasitic phase begins when transformation is complete and prey are available. Downstream movement of transformed adults has been reported by Bigelow and Schroeder (1953) in November and December and by Scott and Crossman (1973) from October to May.

Although entrainment of all life stages is possible, the adhesive nature of lamprey eggs, the benthic nature of the ammocete, and the adults' strong swimming ability and capacity for avoiding strong currents make these phases unlikely candidates for entrainment. However, the recently transformed adults are potential organisms for entrainment.

12 - Issue: Effect of Flood Skimming on the Connecticut River's Prolasmidonta heterodon, Inverted Floater, Populations -- This mussel, once common in the Connecticut River, is a prime candidate for endangered species status (Smith, 1980a). Recent intensive surveys produced only one empty shell in South Deerfield, and a small group of live animals have been reported at Windsor Locks (Smith, 1980c). The decline of this species has been attributed to habitat destruction and pollution. Habitat destruction is usually the result of channelizing, damming, stream flow regulation and road and bridge construction. Oil spills and sedimentation and erosion caused by bridge construction severely disturbed two stream populations elsewhere in Massachusetts (Smith, 1980a).

Goniobasis virginica, the Virginia river snail, is also considered endangered in the Connecticut River (Smith,

1980b). New England is the northeastern limit of this snail's range. An inhabitant of shallow rocky reef areas, it is currently found only between the Enfield-Suffield area and Warehouse Point, Connecticut. Historically, the river snail's range was a 60-mile stretch of river. Smith (1980b) attributed the range contraction to decreases in water quality. He also noted that this snail is periodically stranded during short term water fluctuations caused by human activities.

Crangonyx pseudogracilis, river amphipod, is another Connecticut River invertebrate whose habitat needs careful consideration (Smith, 1979). This species inhabits lowland rivers and ponds (Smith, 1977), and is found in the Connecticut River and its floodplain (Smith, 1979), the Quinnipiac River, and tributaries of the Mystic and Merrimack Rivers. Breeding takes place in the spring in shallow backwater areas and during this period, organisms are susceptible to periodic stranding by decreases in river stage.

In order to determine the impact of flood skimming on these invertebrates, a model is needed to determine changes in river stage in areas where populations are known to occur, or have occurred recently. (Windsor Locks and the Route 116 Bridge in Sunderland for the mussel and Enfield-Suffield area to Warehouse Point, Connecticut for the snail.) Water quality changes should also be determined for these areas.

13 - Issue: Effect of Flood Skimming on Connecticut and Merrimack River Estuarine Communities -- Flood skimming could alter the amount of freshwater reaching the estuary which could, in turn, affect water flow, salinity, temperature, turbidity, and nutrients (Westerfield and Kennard, 1973), ultimately affecting estuarine communities. Information on aquatic communities in the Connecticut River estuary is adequate (Westerfield and Kennard, 1973, Marcy, 1976a, Massengel, 1976). Similar information for the Merrimack River is dated (Jerome et al., 1965) and field studies are recommended to obtain current information on benthic invertebrates and finfish. However, a model must first be developed to determine if stage effects of flood skimming extend to the upriver limit of the estuary. Information on changes in: water flow, salinity, temperature, turbidity and related water quality parameters, resulting from skimming, must be evaluated. A significant change in salinity and salt wedge distribution in the estuary could cause changes in distribution of marine benthic populations. Temperature increases may allow higher rates of development, reproduction and metabolism, whereas turbidity affects the depth of the photic zone and hence primary productivity. Nutrient levels also affect phytoplankton populations and a decrease could affect primary productivity (Westerfield and Kennard, 1973).

Ecology, Floodplains and Tunnel ROW's: General Considerations
Floodplain communities are dependent upon a regimen of springtime flooding, in the absence of which natural change through the process of succession occurs. Changes in the floodplain are accompanied by changes in wildlife use patterns and ultimately, changes in wildlife populations. The effects of flood skimming during spring freshet flows are dependent upon the relationship between stage reduction following a pumping event and the stage necessary to inundate the floodplain to its landward limit (this limit is based on the occurrence of significant proportions of plant species dependent upon seasonal flooding.) Computer simulation of flood skimming effects on river stage is needed in order to predict effects on various floodplain community types such as floodplain forest, wet meadow, point bar, and oxbows of different ages. The effects of changes in stage due to flood skimming can then be determined by comparing stage elevation on the floodplain at the minimum allowable CFS to the stage and CFS necessary to flood the landward limits of the floodplain community. Species components of each of the floodplain plant community types will serve as indicators of those types using a significant proportion criterion of greater than 50 percent. Effects of spoil pile disposal along tunnel ROW's is dependent upon the vegetative communities and wildlife species existing in the disposal areas, on the uniqueness of the plant communities and wildlife habitats, and on the occurrence of rare or endangered species. Effects of spoil pile disposal can be determined by comparing design data to the tolerances and requirements of indicator species.

Northfield Alternative -- Vegetative communities of the Connecticut River floodplain have been recently studied, and data relevant to composition and structure is adequate to assess the impacts of flood skimming. Data on bird populations is available only for certain plant communities, and data on mammals and herptiles is completely lacking. Field studies are recommended to characterize bird, mammal and herptile populations in each floodplain community type in order to assess flood skimming effects. Computer simulation of stage effects will be needed to define the downriver limit of the study area. Vegetative and wildlife populations of the tunnel ROW in the vicinity of proposed spoil pile disposal areas have been described, and this data is adequate to assess the effects of spoil dumping.

Merrimack River Alternative -- Baseline data on the vegetative and wildlife communities of the Merrimack River floodplain is not adequate to assess the effects of flood skimming. Field studies are recommended to characterize the plant communities and their bird, mammal and herptile populations. Computer simulation of stage effects will be needed to define the downriver limit of the study area.

Millers River Alternative -- Baseline data on the vegetative and wildlife communities of the Millers River floodplain is not adequate to assess the effects of flood skimming, and

field studies are recommended to characterize these communities from the intake point to the confluence with Connecticut River. Site specific data on the vegetative and wildlife populations of the tunnel ROW is lacking, and field studies are recommended to provide this data in order to assess the effects of spoil pile disposal.

Desalinization Alternative -- Considerations pertaining to the ecology of floodplains and tunnel ROW's do not apply here.

Ecology, Floodplains and Tunnel ROW's: Discussion of Issues

A synoptic evaluation of information pertaining to floodplain and tunnel right-of-way (ROW) related issues is presented in Table 1-5.

14 - Issue: Effects of Flood Skimming on Revegetation and Erosion Control -- There have been a number of recent studies pertaining to erosion, erosion control and revegetation on the Connecticut River. Similar information is not available for the Merrimack or Millers Rivers but findings of the Connecticut River studies are applicable. The most comprehensive study to date, conducted by the Corps of Engineers (Simons et al., 1979), analyzed the mechanisms and causes of erosion. Similar studies (Kurz, 1979; Wirt, 1980) assessed the effects of fluctuating water levels on stream bank erosion. Results of these studies show that rapidly fluctuating water levels are a major erosion force but that the primary cause of bank erosion is high river velocity during large flows.

Both the Army Corps study and the Northeast Utilities streambank erosion control program (Don Wirth, 1980) have demonstrated that vegetation helps prevent erosion where the bank is shallow and roots penetrate deep. In areas where banks are high the lower banks are not stabilized ized by roots and the weight of trees contributes to slumping. The Northeast Utilities erosion control program consists of removing trees by helicopter, rip-rapping, fertilizing cut areas to encourage stump sprouting, planting mixtures of grasses and legumes and handplanting willow saplings. This program has been successful despite fluctuating water levels. The mechanisms of natural revegetation have also been studied. Sand flats on the Hudson River formed by dredging between 1929-1937 exhibited retarded succession except in limited areas shaded by cottonwoods (McVaugh, 1957). Investigations of seedling establishment and emergence on the Connecticut River (Zeitler, 1978; Sackett, 1977) have demonstrated the dependence of seedling success on water level, and that fluctuations strongly influence patterns of vegetation establishment.

TABLE 1-5 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Ecology, Floodplains and Tunnel ROW's

	Issues	Necessary Information	Status of Existing Information
14-	Effects of flood skimming on revegetation and erosion control along the river. (Connecticut, Millers & Merrimack Rivers)	Effects of skimming on erosion rate; mechanisms of erosion; effect of tidal action on establishment of vegetation; artificial revegetation.	Existing information is adequate to address the issue.
15-	How and where would reduced flooding effect succession on the floodplain. (Connecticut, Millers & Merrimack Rivers)	Species composition, seral stages, successional patterns, and distribution of floodplain communities; effects of skimming on river stage.	Plant community information is adequate for the Connecticut; data inadequate for Millers & Merrimack; distributions available for all; skimming impact on stage to be assessed.
16-	Will alien plants adapted to dryer soil invade agricultural fields (Connecticut River)	Species composition and structure of fields in progressive stages of abandonment along a moisture gradient in the floodplain.	Existing information is partly adequate to address the issue.
17-	Effects of reduced flooding on fertility of agricultural land in western Massachusetts and Connecticut (Connecticut River)	Soil nutrient data for fields in progressive stages of abandonment along a moisture gradient in the floodplain.	Existing information is partly adequate to address the issue.
18-	Effects of reduced flooding on wildlife activities and habitats on the floodplain (Connecticut and Merrimack Rivers)	Species composition seral stages, successional patterns, and distribution of floodplain communities; effects of skimming on river stage; wildlife inventory data, habitat requirements.	Plant community and bird inventory data are adequate for the Connecticut, but mammal and herptile data are needed; plant and wildlife data inadequate for Millers and Merrimack; distributions available for all; skimming impact to be assessed.
19-	Effect of increased tidal amplitude on waterfowl breeding behavior. (Connecticut, Millers and Merrimack Rivers)	Waterfowl species which regularly breed in floodplain communities of each river and their requirements with respect to water level.	Existing information is adequate to address the issue.

TABLE 1-5 (Continued)

	Issues	Necessary Information	Status of Existing Information
20-	Wetlands alterations under Massachusetts and Connecticut wetlands protection acts (Connecticut, Millers and Merrimack Rivers)	Interpretation of laws as to jurisdiction in terms of habitats affected, and wetland functional values; inventory of floodplain, river and ROW wetland types; functional values of wetland types; effects of skimming on river stage.	Wetland statutes, inventories, and information pertaining to functional values are available for all three rivers and tunnel ROW's; skimming impact to be assessed.
21-	Effects of possible changes in the distribution of the salt wedge due to reduced freshwater flows on plant communities. (Connecticut and Merrimack Rivers)	Species composition, seral stages, successional patterns, and distribution of lower floodplain communities; effects of skimming on freshwater flow to the lower river.	Plant community data are adequate for the lower Connecticut; data inadequate for the Merrimack; distributions available for both; skimming impact to be assessed.
22-	Effects on rare and endangered plants and wildlife. (Connecticut, Millers and Merrimack Rivers).	Records of occurrence of r&e plant species; active breeding or nesting sites, overwintering or migratory stopover areas, habitat requirements; effects of skimming on river stage; location and size of spoil piles.	Existing information is adequate to address the issue; skimming impact to be assessed.
23-	Effects of flood skimming and ROW spoil piles on conservation lands and wildlife management areas (Connecticut, Millers and Merrimack Rivers).	Locations of wildlife management areas, species managed; locations of town owned conservation lands; effects of skimming on river stage; location and size of spoil piles.	This information will be obtained from existing sources; skimming impact to be assessed.
24-	Effects of ROW spoil piles on representative species in each habitat and on their habitats (Connecticut and Millers options).	Species composition and distribution of upland vegetative communities; wildlife inventory data, habitat requirements; location and size of spoil piles.	Existing information is adequate to address the issue.

15 - Issue: How and Where Would Reduced Flooding Affect Succession on the Floodplain -- The species composition and successional patterns of various Connecticut River and Mill River floodplain communities are described in several recent and ongoing investigations. Similar information for the Merrimack and Millers Rivers is lacking and field studies will be necessary to fill these information gaps (Recommended Studies). However, the floodplains of all three rivers have been mapped (MacConnell, 1972). Species composition and diversity of three Connecticut River floodplain communities in different stages of development have been analyzed in relation to soil characteristics and flooding (Sackett, 1977). In a similar study, the growth rates of trees at various elevations on the floodplain were measured (Pfeiffer, 1978). Results of these studies indicate that growth conditions for floodplain vegetation are optimal under normal river flows, that a permanent drop in water level will increase the rate of succession, and that fluctuating water levels will maintain the floodplain community in a stage characterized by plant species which are adapted to an unstable flooding regimen.

A study of Connecticut River floodplain transition zones has recently been completed (ERCO, 1980). For this study, data on species composition and community structure were generated in five different floodplain communities in Northampton and Hatfield, three of which had been studied previously (Sackett, 1977). A similar study, on the lower part of the river, currently being conducted by the Connecticut Department of Environmental Protection (DEP), will be completed by fall, 1980. Data on species composition and community structure are being analyzed in relation to soil characteristics, flooding and tidal effects.

On the Mill River, studies of floodplain vegetation were conducted at various periods during and following disturbance by pollution and oil spills (Robinton and Burk, 1971; Burk, 1973; Burk, 1977). Results of these studies demonstrated that portions of the floodplain disturbed by pollution had lower species diversity and vegetative density than portions which were undisturbed, and that diversity and density increased following pollution abatement. The roles of various species in succession during disturbance and recovery are discussed.

Successional patterns in standing or flowing water have also been studied. Seddon (1972) placed species of submerged and floating-leaved aquatic plants into different groups based on their roles in different hydric successional stages. Species are listed in relation to their occurrence in the various stages.

16 - Issue: Will Alien Plants Adapted to Dryer Soils Invade Agricultural Fields -- Due to the much higher acreage of

floodplain agricultural land along the Connecticut River compared to the Millers and Merrimack Rivers, this issue is significant only to the first alternative. To understand whether reduced flooding or alterations in flow will cause alien weeds to invade cropland it is necessary to know the community characteristics of fields in progressive stages of abandonment at various floodplain elevations. An investigation is currently in progress to determine the structure, composition and successional patterns of fields in three successive stages of abandonment in relation to soil types and flooding (Walker). Results of this study will be available by early summer, 1980.

17 - Issue: Effects of Reduced Flooding on Fertility of Agricultural Land -- By reason of the higher acreage of floodplain agricultural land along the Connecticut River compared to the Millers and Merrimack Rivers, this issue will be addressed only in relation to the Northfield alternative. To determine the effects of reduced flooding on the fertility of cropland, nutrient contents of soils and vegetation of fields in different stages of abandonment at various elevations in the floodplain must be known. A study has been conducted to determine the concentrations of mineral elements in various plant parts of species on a floodplain in the southeastern U.S. (Garten et al., 1977). Results of this study indicated that distributions of elements were positively correlated with distance from the river. A similar investigation is being completed on the Connecticut River (Walker). Mineral content of soils and plants from three successive stages of abandonment are being analyzed in relation to successional stage and flooding. Results of this study will be available by early summer, 1980.

18 - Issue: Effects of Reduced Flooding on Wildlife Activities and Habitats on the Floodplain -- From information generated by the vegetation studies pertaining to species composition and structure of Connecticut River floodplain communities, it is also possible to assess wildlife habitat conditions. As previously mentioned, however, descriptions of Millers and Merrimack River floodplain communities are lacking and field studies will be necessary to characterize wildlife habitats, although the floodplains of all three rivers have been mapped (MacConnel, 1972). The only information available on wildlife populations in floodplain communities is a field study in progress on the Connecticut River (Hubley). Bird inventories are being conducted in three different floodplain communities, and species data will be correlated with factors such as vegetation structure and flooding. Results of this study will be available by late 1980. Information of a more general, less site specific nature pertaining to wildlife activity on the Connecticut River and certain tributaries is available in two studies (U.S. Fish and Wildlife Service, 1970; Center for the Environment and

Man, 1976). Since mammal and herptile data are lacking, (Snyder, 1980) field studies should be conducted within each of the floodplain community types. Because there are no wildlife inventory data available for the Millers or Merrimack Rivers, bird, mammal and herptile studies will be conducted in representative floodplain communities. The various habitat types that have been mapped along the three rivers will be color coded.

19 - Issue: Effect of Increased Tidal Amplitude on Waterfowl Breeding Behavior -- Information pertaining to waterfowl breeding activity and locations of important habitats is available for both Massachusetts and Connecticut portions of the Connecticut River and for the Merrimack and Millers Rivers. The major waterfowl species breeding on these rivers are the mallard, black duck and wood duck, and the most important habitats for breeding and brood rearing are deep marsh and shrub-swamp; for the wood duck mature floodplain forest is also important (Heusmann, 1980). These habitat types will be color coded on the existing MacConnel maps. Due to its east-west orientation, the Merrimack River is not important for migrating waterfowl, but the Connecticut River is regularly visited by American and red-breasted mergansers, bufflehead, goldeneye and geese. Waterfowl are apparently indiscriminate in their use of the Connecticut River during migration since no habitat preference patterns have been observed.

For the lower portion of the river, in Connecticut, information pertaining to important breeding, overwintering and stopover areas is scattered and will have to be accessed by written request to the Connecticut DEP (Herrig, 1980).

Frequent fluctuations in water level can have a detrimental effect on breeding behavior and can increase brood mortality due to predation. There is experimental evidence that waterfowl use wetlands with a stable water level more than those with fluctuating levels (Heusmann, 1980).

20 - Issue: Wetlands Alterations under Massachusetts and Connecticut Wetlands Protection Acts -- Wetland statutes have been promulgated in Massachusetts and Connecticut which regulate activities that alter wetlands. Included in the descriptions of these statutes are definitions of the kinds of habitats under statutory jurisdiction, and the functional values which are protected. Wetland habitats occurring within the flowages and floodplains of the Connecticut, Millers and Merrimack Rivers, and along the proposed Northfield and Millers tunnel ROW's have been mapped (MacConnel, 1972). The symbols that have been assigned to mapping units in the floodplains will, in most cases, have to be changed and recoded using color. A system for evaluating the various wetland types as wildlife habitat has been developed (Golet and Larson, 1974), and pollution preven-

tion values of different wetland types have been studied (Spangler et al., 1976; Boyt et al., 1977). This information will be used to assess the impacts of diversion on wetland values.

21 - Issue: Effects of Possible Changes in the Distribution of the Salt Wedge due to Reduced Freshwater Flows on Plant Communities -- To determine the effects of salinity changes on plant communities, it is necessary to know the species composition and distribution of Merrimack and Connecticut River lower floodplain communities, and salt tolerances of the major species. Characteristics of the lower Connecticut floodplain communities were described in a recent study (Coleman, 1978). A study by the Connecticut DEP, currently in progress and scheduled for completion in fall, 1980, is analyzing species composition of floodplain communities in relation to soil characteristics, flooding and tidal effects. Information pertaining to lower Merrimack floodplain communities is available (Normandeau Associates, 1974) but is incomplete, and supplementary field study will be necessary to characterize vascular plants and macroalgae. However, a model must first be developed to determine if stage effects of flood skimming extend to the upriver limit of the estuary. The lower floodplains of both rivers have been mapped (MacConnel, 1972). The growth rates of 10 species of aquatic macrophytes were studied and found to vary widely depending on salt tolerance of the species (Haller et al., 1974).

22 - Issue: Effects of Flood Skimming on Rare and Endangered Species and Their Habitats -- There is little published information regarding the status of rare and endangered species on the Connecticut, Millers or Merrimack Rivers. However, there is a substantial body of existing information pertaining to current status of rare and endangered species available through personal communications with individuals and agencies involved in various surveys and investigations. In their study of rare and endangered plant species of Connecticut, Dowhan and Craig (1976) list species of plants possibly occurring in the floodplain of the Connecticut River. However, in a report on the interrelationships between electric power generation and natural resources prepared by the Federal Power Commission (1976) it was concluded that there are no known endangered and threatened species dependent upon the habitats provided by the Connecticut River Basin. In vegetation and wildlife studies along the proposed tunnel ROW, Carlozzi et al (1976) concluded that "there are no endangered species or ecosystems that would be affected by the proposed project."

Dr. Leslie Mehrhoff, Connecticut DEP, was able to provide information on rare plant locations and on rare and endangered birds for the Connecticut portion of the river. Mr. Tom Hoehn, Connecticut DEP, indicated that there are four

active osprey nests below Saybrook, in the estuary, but none above. He also stated that there are no eagles nesting along the Connecticut portion of the river, but that several birds overwinter in the estuary and the upper river near the Massachusetts line. Mr. Richard Forster, in charge of the Nesting Bird Atlas Program for Massachusetts Audubon Society, indicated that there are no known nesting sites of federal or state rare or endangered wildlife along the Massachusetts portion of the Connecticut River and thought that breeding activity by such species would be unlikely. Ms. Martha Fisher, program coordinator for the rare and endangered species portion of the Natural Heritage Program, indicated that information pertaining to locations of rare and endangered plants and wildlife was currently being assembled for Massachusetts. Information for the Connecticut, Millers and Merrimack Rivers should be available by summer, 1980.

23 - Issue: Effects of Flood Skimming and Tunnel ROW Spoil Piles on Conservation Lands, Natural Areas, and Wildlife Management Areas -- All existing information pertaining to conservation lands, natural areas and wildlife management areas is available through personal communications with various state and local agencies. Mr. Robert White, director of the Connecticut DEP Natural Areas Survey, was contacted for information relevant to locations of natural areas on the Connecticut River floodplain. He indicated that such information has been recorded on topographic maps and would be available if he could be supplied with names of the towns occurring along the river. Ms. Martha Fisher, of the Massachusetts Natural Heritage Program indicated that Massachusetts does not designate natural areas as such, but defines areas worthy of preservation mainly on the occurrence of unusual natural features or rare and endangered species locations.

Staff of the Connecticut DEP Wildlife Unit and the Massachusetts Division of Fish and Game were contacted regarding the occurrence of wildlife management areas within floodplains of the Connecticut and Merrimack Rivers. Both departments indicated the existence of major and minor management areas and sanctuaries on these rivers, and that if requested, the areas could be designated on topographic maps. There are no management areas anywhere along the proposed tunnel ROW's.

Information regarding specific locations of town-owned conservation lands relative to Connecticut, Millers and Merrimack River floodplains can be obtained by contacting the conservation commissions of towns occurring along these rivers. This information can then be plotted on topographic maps.

24 - Issue: Effects of Tunnel ROW Spoil Piles and Other Structures on Representative Species and Their Habitats --Wildlife and vegetation of the Northfield tunnel ROW and impacts of the ROW have been assessed in two recent investigations.

Engineering considerations relevant to the number, location, and size of spoil piles, access shafts, roads and staging sites are discussed in a report by Farquahar (1976). The vegetation and wildlife present at each of the sites along the ROW, and impacts of the ROW are presented in a very comprehensive and thorough report by Carlozzi et al (1976). The information contained in these reports is adequate to assess the impacts of the ROW on representative species and habitats without the necessity for additional field study. The effects of spoil disposal on the Osgood Brook, Great Blue Heron Rookery will also be addressed. Similar site-specific information for the Millers River ROW is lacking.

Ecology, Coastlines: General Status of Existing Information

At this stage, the proposed location and design of the desalinization plant have not yet been clearly defined, therefore any appraisal of the status of existing information must be of a provisional nature. However, certain assumptions regarding design have been made and have provided a basis for identifying the issues and information needed to address the issues.

The plant will have an intake structure and will pump seawater at a certain volume per unit time, therefore impingement and entrainment of macroinvertebrates and larval fish constitute a major issue (Table 1-6). Disposal of concentrated saline solution near shore is another issue which carries the potential for environmental damage and must be addressed.

To address the issues of potential impingement and entrainment and disposal of concentrated solution species composition and structure of macroinvertebrate and finfish communities of near shore waters in the vicinity of the plant must be known. Detailed field investigations of these communities have recently been performed in connection with licensing of Pilgrim I and II nuclear power stations in Plymouth. The need for additional field studies is therefore not anticipated if this site is selected.

TABLE 1-6 ISSUES, NECESSARY INFORMATION AND STATUS OF EXISTING INFORMATION

Ecology, Coastlines

	Issues	Necessary Information	Status of Existing Information
25-	Entrainment and impingement of macroinvertebrates, ichthyoplankton and larvae in the plant intake system.	Inventory data for macroinvertebrates and fish of near coastal waters in the vicinity of the proposed site; plant specifications including pumping rates, hours of operation etc.	Inventory data are adequate to address the issue if facility is sited in Plymouth; plant specifications needed.
26-	Disposal of concentrated saline solution.	Plant specifications including unit time volume and concentration of solution.	Plant specifications needed.

RECOMMENDED FIELD STUDIES

Northfield

Water Quality: The objectives of a water quality sampling program on the Connecticut River are to: 1) investigate whether pumped withdrawals immediately affect water quality in downstream stretches of the river (see Discussion of Issues) and 2) support calibration and verification of a mathematical water quality model (if required). Sampling should include constituents and characteristics which are known to affect oxygen depletion rates (e.g. BOD, water temperature, flow rate, time-of-travel, and reduced forms of nitrogen) plus other commonly accepted water quality indicators (e.g. fecal coliform counts, pH, total phosphorus, nitrate-nitrogen, turbidity, and total solids). Sampling should occur during the hours when river water is being pumped to Northfield Mountain Reservoir (i.e. before 6:00 a.m. on weekdays, before noon on Sundays). To compare water quality conditions in the absence of drawdown, an identical survey should be conducted during the daytime.

To evaluate river water quality variability, two depth intergrated grab samples will be taken from both east and west sides of the main channel, for a total of at least four samples per station. Sampling stations should be responsive to mathematical model requirements but should include as a minimum: 1) the intake point (approximate river mile 129), 2) confluence with the Millers River (approximate river mile 127), 3) Montague gauging station, immediately below confluence with the Deerfield River (approximate river mile 120), and 4) a control point upstream from the intake.

Sampling would be timed to coincide as closely as possible with downstream arrival of the "plug" of river water from which pumped withdrawal had been made. This may or may not precede time-of-travel. U.S. Army Corps of Engineers' data on flow-related stream channel geometry, developed in con-

nection with a stream bank erosion study (C. Wiener, New England Division, C. of E. personal communication), may be helpful in synchronizing the sampling survey.

To maximize the likelihood of detecting water quality impact, sampling surveys should be conducted on a Sunday (when pumps are running longer) and also on several consecutive weekdays (when industrial plants are busier) over several weeks. Surveys should be scheduled in late spring or early fall when the warmest water at flows above the 17,000 cfs are most likely to occur. Computer simulations of water supply skimming impact would probably only be necessary if results of surveys, performed as described above, gave evidence of significant drawdown-related water quality degradation. In the absence of a demonstration that four to ten hours of skimming affects water quality, the hypothesis that an additional 1-1/4 hours of pumping degrades water quality has little credibility.

Ecology, Rivers, Tributaries and Estuaries: The existing data base is adequate to assess flood skimming effects, therefore no additional field studies are recommended.

Ecology, Floodplains and Tunnel ROW's: Floodplain vegetative communities, wetlands and important waterfowl habitats will be color coded on "Massachusetts Mapdown" maps. The color coded maps will be used in conjunction with topographic maps as aids in selecting field sampling locations for wildlife studies, and in assessing flood skimming effects on floodplain communities.

Birds will be studied within each floodplain community type by means of transects placed within each of several areas representative of each community type. The transects will be walked during the first two hours of daylight, and listening stations established every 100 yards for five minutes. The data will be used to measure diversity and to determine size of the breeding bird population per unit area.

Small mammals will be studied within each floodplain community type using live trapping and mark-recapture techniques. Two crossed trap lines placed approximately in the center of the area, each 50 m long, with the traps spaced every 2 m will be the design used; this will provide a trap area of 2,500 m^2. Traps will be baited with peanut butter, oatmeal and bacon fat, and captured animals will be marked with red or orange dye according to the line, and released. The data will be used to derive population estimates for each species captured.

Winter track surveys will be conducted within each floodplain community to obtain species lists of medium-size mammals, detect deer activity and augment the small mammal species list derived from the live trapping effort.

Reptiles and amphibians will be inventoried within each floodplain community. Likely habitats such as rotting logs, shallow pools, tributary streams and the river edge will be investigated both at night and during the day and species lists generated for each type.

Ecology, Coastlines: Considerations pertaining to coastline ecology do not apply here.

Merrimack River

Water Quality: The objectives of a water quality sampling program on the Merrimack River are to: 1) characterize daily and weekly river dynamics during freshet months when skimming would occur and 2) support calibration and verification of a mathematical water quality model if such were found to be necessary. Sampling will be for the same parameters as in the Northfield alternative. Two depth-integrated grab samples will be taken from east and west sides of the main channel for a total of four samples per station. Sampling stations will include, as a minimum, a station at a control point above the diversion, a station at the diversion, and one below. Sampling will be conducted on several consecutive days and nights over several weeks. Surveys should be scheduled during spring when flood skimming would occur.

Ecology, Rivers, Tributaries and Estuaries: Finfish populations will be sampled at five sites on the Merrimack River from the mouth to Tyngsboro. These sites will be at stations previously surveyed by Massachusetts Division of Fisheries and Game (Oatis and Bridges, 1969). Seining will be conducted at east and west littoral regions of each site and gill nets will be set in deeper areas and fished overnight. Finfish captured will be identified, enumerated and measured.

Aquatic macroinvertebrate populations will be surveyed at the five finfish sampling locations. At each site replicate Ponar grabs will be taken at each bank and at mid-channel. Samples will be sieved, stained and fixed in the field, then returned to the laboratory for sorting, identification and final preservation.

Ecology, Floodplains and ROW's: "Massachusetts Mapdown" maps will be color coded as discussed in the Connecticut River alternative to be used in selecting field sam-

pling locations for vegetation and wildlife studies, and in assessing flood-skimming effects on floodplain communities.

Data on floodplain communities will be collected using a stratified random sampling approach. Sample plots will be randomly selected within each of several areas representative of each community type (e.g. marsh, shrub swamp and seasonally flooded types). The number of plots sampled within a given type will be proportional to its size in relation to the combined size of all areas sampled.

Where trees are present and provide at least 30 percent canopy cover species composition, diameter and relative canopy position will be determined at each sample location. Sample trees will be selected using a 10 factor wedge prism. Relative frequency will be measured for each species by dividing total sample location occurrences of the species by the total of all occurrences.

The center of the location used for sampling the tree layer will also serve as the center of a 2m x 2m plot for sampling saplings and shrubs. Species within the plot will be recorded and a cover/abundance estimate made for each species. This is a visual estimate of abundance and crown cover for each species on the plot. Relative frequencies will also be measured. Herbaceous plants will be sampled on 2m x 1m plots within the larger shrub sampling plots. Cover/abundance and relative frequency will be determined for each species. Sampling procedures for trees, shrubs and herbs will be as outlined above whether the various strata are layered or occur separately as dominants in other types. To ensure a thorough representation of the components of each plant community, a separate species list, in addition to the plot lists, will be generated for each type.

Macroalgae will be sampled at locations from the mouth of the river to the Essex Dam. This point was chosen as the upriver limit of macroalgae studies because it is not anticipated that any diversion effects on salinity changes would extend beyond the dam. However, a model must first be developed to determine if stage effects of flood skimming extend to the upriver limit of the estuary. Relative frequency will be determined for each species. Studies of birds, mammals, reptiles and amphibians will be as discussed in the Connecticut River alternative.

Ecology, Coastlines: Considerations pertaining to coastline ecology do not apply here.

Millers River

Water Quality: The objectives of a water quality sampling program on the Millers River are to: 1) characterize daily

and weekly river dynamics during spring freshet months when skimming would occur and 2) support calibration and verification of a mathematical water quality model if such were found to be necessary. Sample design and timing will be as discussed in the Merrimack River alternative with a station at a control point above the intake, a station at the intake and one below.

Ecology, Rivers, Tributaries and Estuaries: The sample design that will be used in sampling to characterize finfish and invertebrate communities will be as discussed in the Merrimack River alternative. Sampling will be conducted at stations previously surveyed by Massachusetts Division of Fish and Game.

Ecology, Floodplains and Tunnel ROW's: The "Massachusetts Mapdown" maps will be color coded as discussed in the Connecticut River alternative, to be used in selecting field sampling locations for vegetation and wildlife studies and in assessing flood-skimming effects on floodplain communities. Studies of vegetation, birds, mammals, and herptiles of the various floodplain community types and the tunnel ROW will be conducted using the methods discussed in the Connecticut River and Merrimack River alternatives.

Ecology, Coastlines: Considerations pertaining to coastline ecology do not apply here.

Desalinization

The existing data base is adequate to assess desalinization impacts and no additional field studies are recommended if the facility is sited in Plymouth.

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U.S. Fish and Wildlife Service, Northeast Region. 1970. Comprehensive Water and Related Land Resources, Connecticut River Basin; Appendix G, Fish and Wildlife Resources.

Walker, Marcia. Graduate student, Smith College Dept. of Botany, unfinished M.A. thesis.

White, Robert. Conn. DEP Natural Areas Survey; locations of natural areas on the Conn. River floodplain.

Wirt, Laurie. Senior honors student, Amherst College Dept. of Geology; study of erosion on point bars upriver from Northfield pumped storage.

Wirth, Don. Northeast Utilities; causes of erosion and erosion control methods.

Zeitler, P. S. 1978. Seedling establishment of floodplain species at two sites along the Connecticut River in Northampton Mass. Senior Honors Thesis, Amherst College Dept. of Biology.

RESPONSES TO QUESTIONS AND COMMENTS ON DRAFT TECHNICAL MEMORANDUM

NORTHFIELD CITIZENS ADVISORY COMMITTEE (NCAC):

1) Q-Table 4-2, Summary of adequacy of existing information. A precise definition of "adequate" and "inadequate" should be presented so the reader knows exactly how issu were divided into the two categories.

A-Determinations of adequacy were based on the professional judgement of the investiga

2) Q-Table 4-1, Connecticut River Indicator Species. It appears that this list was drawr from Table 3 and Appendix E of NCAC's Report on Indicator Species. If so, then refe ence should be made to NCAC's report. Is the scientific name for Northern Pike Esox niger or Esox Lucius? What exactly do these species indicate?

A-Scientific name for Northern pike is Esox lucius. The species on the indicator list include representatives of various trophic levels and species of concern due to stat or federal rare or endangered status. These species are indicators of the existing aquatic environment of the Connecticut River.

3) Q-Chapter 4, Introduction. The phrase "flood skimming" should be defined. Considerat should be given to the impacts of instantaneous draw-downs during any pumping regime on "river flows above intake points".

A-"Flood skimming" is defined in the engineering description of alternatives.

4) Q-Chapter 4, Methods. It is assumed that the reference to "proceedings of conferences on the Northfield Project" relates to workshops sponsored by the Institute for Man and Environment in 1975 at the University of Massachusetts Amherst campus, but a reference should be given. On what page does Section 5.0 start?

A-The reference relates to a workshop on Amherst College campus in 1979, and one in Enfield, Connecticut in 1980. Section numbers have been eliminated from this report

5) Q-Table 4-3, Matrix of water supply alternatives and water quality, aquatic ecology a terrestrial ecology issues from Tables 4-2 through 4-5. Since reference is made to Four alternatives in the introduction (Connecticut River, Connecticut River Tributaries, the Merrimack River and a coastal desalination site) why is "Northfield Tunnel Row" treated as a separate alternative? and why are "Connecticut River" and "Connecticut River Tributaries" lumped together? would it make sense to combine Tables 4-2 and 4-3?

A-Tables 4-2 and 4-3 have been combined and are now Table 1-2. The four alternatives in the tables have been made consistent with those referred to elsewhere in the memorandum.

6) Q-Evaluation of existing data, Water quality: general status of existing information The Westfield and Chicopee Rivers have also been sampled by the MDWPC. In citing t Spring 1978 sampling program of the MDWPC, attention should be paid to the frequenc of sampling and the location of sampling sites. Ms. Susan Cole, former 208 planner LPVRPC, indicates these samples were obtained only on one day, and therefore more data are necessary for development of "a mathematical water quality model". (see attached comments from D.W. Stickel).

A-NAI does not believe that data taken on one day in the Westfield and Chicopee Rivers is relevant to assessing effects of flood skimming on the Connecticut and Millers Rivers.

7) Q-Chapter 4, Summary, second paragraph. NCAC does not believe that water quality information on the Connecticut and Merrimack Rivers is adequate. NCAC doubts that sufficient data on lamprey will be available in summer 1980.

A-Agree that water quality data is inadequate to assess flood skimming effects.

8) Q-Table 4-1. The true generic name for River mussel is Prolasmidonta.

A-Correction has been made.

9) Q-Table 4-2. There are few data on 5 (information is just becoming available). Item 9 is an incredibly broad category, some data is sufficient, others not. No data are available as yet on #10, 11, or 24.

A-NAI is in agreement regarding status of information relevant to Items 5, 9, 10 and 11. However, data is available on Issue 24 (Carlozzi et al., 1976).

10) Q-In the future NCAC requests that all pages be numbered for adequate reference.

A-Pages have all been numbered.

11) Q-Evaluation of Existing Data, Water Quality: General Status of Existing information. NCAC maintains that "grab samples taken approximately monthly" that are "typically confined to the summer months" are not adequate for a sound assessment of water quality. NCAC recommends that monitoring of water quality, parameters be undertaken on a consistent and regular basis throughout the year. (see NCAC statement on the Issue of Diversion and NCAC's Report on Indicator Species.) R. Hubley comments "Before any diversion takes place, water quality in the Connecticut River from the point of proposed diversion on downstream must meet State and Federal water quality standards. If the diversion is affected, there should be continuous water quality monitoring both upstream near the intake point and downstream at a stretch of river identified by Federal Water Quality Agencies as having the lowest water quality in the river. Furthermore, no water should be diverted in any year in which any part of the river does not meet Federal and State water quality standards. The parameters that should be continuously monitored are those listed in the "Joint Statement" on the Issue of Connecticut River Diversion (adopted by the Connecticut and Massachusetts Steering Committee on the Connecticut River in March of 1977).

A-Agree that water quality data is inadequate to assess flood skimming effects; a sampling program is recommended.

12) Q-Where are water quality data collected by Aquatec, Inc. maintained? Are these data available to interested members of the scientific community?

A-Water quality data collected by Aquatec Inc. is available at the MDC library. A more complete data record would be available by special request from Aquatec.

13) Q-Table 4-4. Under Issue 2A, the phrase "mass balance loading" must be explained.

A-Mass balance loading has been explained in the text.

14) Q-Table 4-4. Under Issue 3, all references should be cited for the statement, "exist information is adequate to address this issue on Connecticut River".

A-Data pertaining to salinity profiles, salt wedge movement and estuarine hydraulics are being collected by the Department of Earth and Environmental Sciences of Wesley University; this data has been collected for more than 5 years and is the most complete data set available.

15) Q-Table 4-4. Under Issue 6, how will information presented here be integrated with Bechtel's Engineering Memo?

A-When design features are known, particularly pumping rates, quantity of water discharged, and salinity concentrations, these data will be used to determine concentr tion gradients which will be compared to tolerance thresholds of the organisms near the site.

16) Q-Issue: Water Quality Degradation. NCAC believes the statement "the water quality impact on downstream reaches of the Connecticut River due to flood skimming at Nort field would be negligible" is inappropriate at this time.

A-The mass balance calculation done for illustrative purposes in the text used total phosphorus, a conservative element, as an example. The conclusion that downstream water quality impact would be negligible was based on a worse case loading which wa compared to downstream concentrations.

17) Q-Issue: River cleansing. What is known now about the movement of fine sediments ir the Connecticut, Millers, Merrimack, or Sudbury River Systems?

A-It is possible to draw inferences from suspended solids data, however there are larger particles that would not be revealed in an analysis for suspended solids; more complete grain size composition data is available from Wesleyan University (see Issue 4).

18) Q-Issue: Donor Stream Compliance with Water Supply Standards. What efforts will be made to insure that water quality standards in the upper pool at Northfield Mountai pumped storage reservoir will be maintained?

A-Do not understand question.

19) Q-Ecology, Rivers, Tributaries and Estuaries: General Considerations. In the summa Table 4-2 it is claimed that data are "adequate"; here it is stated that "data pertaining to Merrimack and Connecticut Rivers aquatic organisms are needed". In response to the statement, "once community characteristics are known, a group of representative species can be selected for more detailed analysis, "NCAC members suggest the consultants give careful consideration to the NCAC's "indicator specie list; each of the species listed by NCAC an an "indicator" was chosen for a very specific reason.

A-The text and table have been changed to remove the inconsistency. The NCAC list o indicator species developed for the Connecticut River is being used for the Northfield Alternative; lists would need to be developed for the Merrimack and Millers Rivers.

20) Q-Issue: Impact of Flood Skimming on Benthic and Finfish Communities. NCAC disagrees that "existing information is adequate to address this issue" for invertebrates. References for "Semour 1966" and "Fast and Coete 1975" are not listed under Literature Cited. How can NCAC members obtain copies of the reports listed?

A-The references are typographical errors; they have been eliminated from the text.

21) Q-Table 4-5, Issue 7. NCAC does not believe "existing information on aquatic communities is adequate for the Connecticut River."

A-NAI believes that the data is adequate for an EIR.

22) Q-Table 4-5, Issue 8. NCAC does not believe "existing life history information is adequate".

A-No comment.

23) Q-Table 4-5, Issue 9. Recent collections of live river mussels have been made by D. Smith of the Museum of Zoology at the University of Massachusetts.

A-The correction has been made in the table.

24) Q-Table 4-5, Issue 10. Life history of sea lamprey is virtually unknown in the Connecticut River (see attached comments from D. W. Stickel).

A-NAI looks forward to working with NCAC to access information from Mass. Coop. Fisheries research unit.

25) Q-Table 4-5. Issues 11 and 13 are closely associated -- NCAC doubts that adequate data are presently available on homing abilities of anadromous fish.

A-Agree that data correlating homing with flow velocities is inadequate; however it has been established that the olfactory sensitivity of anadromous fish is extremely acute. It is highly likely, therefore, that under regularly occurring low flow conditions (e.g., the 2 or 3 year low spring flow) river flow is sufficient to trigger anadromous runs. Effects of flood skimming can be assessed by comparing river flow minus the volume removed for water supply to the natural year to year variation in flow.

26) Q-Issue: Effect of Flood Skimming on Atlantic Salmon and American Shad. The statement that "entrainment is apparently related to percentage of river flow withdrawn" is very important. How will consultants predict percent entrainment when different volumes of river flow are withdrawn? (see attached comments from D. W. Stickel).

A-Entrainment during flood skimming on the Connecticut River will not be significantly different than under existing conditions since the volume pumped to the reservoir will not change. Percent entrainment will be predicted for the Merrimack and Millers Rivers using data for the Connecticut River (see Issue 13) once pumping volumes and rates are known.

27) Q-Issue: Effect of Flood Skimming on Homing Ability of Anadromous Fish, particularly Atlantic Salmon and American Shad -- In appendix J of Vol. IV of the Millers River water supply project (U. S. Army C.O.E., 1974) "Possible effects of various diversions from the Connecticut River (on its estuary), the Essex Marine Lab states that the mechanisms of shad homing should be fully known before any quantities of Connecticut River water are diverted.

A-Effects of diversion on the estuary can be compared to yearly variation in freshet flow to determine whether the volume change at the estuary is within natural range of variation; yearly figures for numbers of shad lifted at Holyoke Dam can then be compared to yearly spring flow records.

28) Q-Issue: Will Flood Skimming Cause Sea Lamprey Entrainment and Transfer to Quabbin Reservoir? NCAC understands that ammocetes (or proto-adults) drift downstream, so they cannot be classified as having a "benthic nature". (see attached comments fro D. W. Stickel). Any stage of the life cycle is a potential candidate for entrainme and a population may be started in Quabbin. D. Smith (museum of Zoology Universit of Massachusetts) comments: "I am convinced that, given sufficient time, lampreys will be entrained and the incipience of a freshwater population is quite possible".

A-The high probability of introducing undesirable species to Quabbin is recognized; various combinations of treatments are possible that would be highly effective in removing all but perhaps a very small percentage of organisms before the water ente Quabbin. These treatments will be investigated in later phases.

29) Q-Issue: Effect of Flood skimming on the Connecticut River's *Prolasmidonta heterodo* Inverted Floater, Populations -- *Crangonyx pseudogracilis* is a river amphipod (crustacean). Doug Smith is presently conducting careful, intensive, systematic surveys of Connecticut River benthos and he should have results by Fall 1980. Smith's work was not published in 1972 -- his paper on *Crangonyx* was published in 1977.

A-Corrections have been made.

30) Q-Table 4-6. Issue 18: Effects of reduced flooding on wildlife activities and habitats on the floodplain. The collection of data on herptiles is important because of recent interest expressed by the State of Massachusetts to protect herps.

A-NAI believes that the information is adequate for an EIR.

31) Q-Table 4-6. Issue 22: NCAC doubts that adequate data are presently available abou effects on rare and endangered plants and wildlife.

A-NAI believes that locational information for rare and endangered species is adequa and that effects can be assessed through reviews of engineering specifications and by modeling physical and chemical parameters.

32) Q-Table 4-6. Issues 23 and 24: what consideration will be given to the effects of tunner drilling?

A-Factors such as noise and vibration level at and just beneath the surface during t drilling and effects of tunnel construction on wetlands will be investigated.

33) Q-Issue: How and where would reduced Flooding affect succession on the Floodplain? ERCO's studies were conducted in Leverett, Whately, Northampton, and Hatfield. Ho useful will the ERCO material be in assessing the impact of reduced flooding on succession?

A-In a phone conversation with ERCO staff it was indicated that considerable data re vant to the composition and structure of various floodplain community types would

available by special request. This data combined with information pertaining to moisture requirements will be very useful in assessing effects of reduced flooding.

34) Q-Issue: Will alien Plants adapted to dryer soils invade agricultural fields? Work completed by Walker (1980) is not sufficient to answer this question.

A-NAI believes that the information is adequate for an EIR.

35) Q-Issue: effect of reduced flooding on old fields -- where is the existing information on this problem? Has work been done to determine the relation between reduced flooding and moisture gradients in floodplain fields?

A-This issue is very similar to the previous one, and the two were treated as one in the text (Issue 16); information being generated in the study by Walker (1980) is relevant to the problem of reduced flooding and old fields.

36) Q-Issue: effects of flood skimming on rare and endangered species and their habitats. In Appendix E of NCAC's Report on Indicator Species, *Acipenser brevirostrum* is listed as endangered, while *Acipenser oxyrhynchus* is listed as rare.

A-Corrections have been made.

37) Q-Issue: Effects of Northfield Tunnel ROW Spoil Piles. Effects of spoil disposal on the Osgood Brook Heron Rookery must be considered. The Great Blue Heron is categorized as an endangered species in Massachusetts.

A-Effects of spoil disposal on the Osgood Brook Heron Rookery will be considered; such has been noted in the text.

38) Q-NCAC suggests that another Issue be added entitled "Effects of tunnel construction on surface lands and wetlands" to assess the possible impacts of construction of any proposed Tunnel ROW (i.e. noise, vibration, dust, etc.).

A-Consideration will be given to adding tunnel construction concerns as a separate issue in a later phase of the study.

PUBLIC MEETINGS:

1) Q-Re Connecticut River data. Need daily sampling data, rather than monthly samples, which are not enough.

A-Agree that monthly sampling is not adequate to assess flood skimming effects; a sampling program is recommended.

2) Q-Based on DEQE information, there is not enough radioactive and pesticide information EPA has some new data, but it may be yearly. Conflicting nuclear information. Data is unanalyzed.

A-Radioactivity data has been collected monthly since the early 70's by Lawrence Labs, of the State Department of Public Health; pesticides are monitored monthly by the USGS.

3) Q-What is meant by fine tuning?

A-Fine tuning refers to a water quality sampling program involving more frequent sampling than was done in generating the existing data sets (USGS, MDWPC), for the purpose of providing inputs to a water quality model.

4) Q-List criteria for determining the adequacy of the data.

A-Assessment of the adequacy of a piece of information is based on the professional judgement of the investigator.

5) Q-Does it make sense to check for lamprey in Turners Pool now?

A-Lamprey in Turners Pool would be adults, and can be easily counted; with informatio on fecundity rates from the literature it is possible to predict numbers of larvae that will be produced and which will be present in the river.

6) Q-What reaches will be modelled?

A-The river reach between Vernon and Turners dams, and from Turners to Montague would be modeled; lower segments would be modeled if necessary.

7) Q-Are there any endangered species?

A-Endangered species are listed in Table 1-1.

8) Q-Information on mussels inadequate.

A-NAI believes that existing information, based on intensive surveys, is adequate for an EIR.

9) Q-Is data adequate to determine various water levels in the Connecticut River?

A-Flow data and river cross sections are available from which to compute river stage.

FEDERAL AND STATE LISTS OF THREATENED AND ENDANGERED FISH AND WILDLIFE IN MASSACHUSETTS[3], NEW HAMPSHIRE AND CONNECTICUT[4]

[3]An official state list is not yet available; the federal list is used.

[4]State list is outdated and no longer available; new list is not available as yet.

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES IN NEW HAMPSHIRE

Common Name	Scientific Name	Status	Distribution
FISHES:			
Sturgeon, shortnose*	Acipenser brevirostrum	E	Atlantic Coastal water
REPTILES:			
Turtle, loggerhead*	Caretta caretta	T	Oceanic summer residen
Turtle, leatherback*	Dermochelys coriacea	E	Oceanic summer residen
Turtle, Atlantic ridley*	Lepidochelys kempii	E	Oceanic summer residen
BIRDS:			
Eagle, bald	Haliaeetus leucocephalus	E	Entire state - migrato
Falcon, American peregrine	Falco peregrinus anatum	E	Entire state - re-establishment to former breeding rang is in progress
Falcon, Arctic peregrine	Falco peregrinus tundrius	E	Entire state migratory no nesting
MAMMALS:			
Cougar, eastern	Felis concolor cougar	E	Entire state - may be extinct
Whale, blue*	Balaenoptera musculus	E	Oceanic
Whale, finback*	Balaenoptera physalus	E	Oceanic
Whale, humpback*	Megaptera novaeangliae	E	Oceanic
Whale, right*	Eubalaena spp. (all species)	E	Oceanic
Whale, sei*	Balaenoptera borealis	E	Oceanic
Whale, sperm*	Physeter catodon	E	Oceanic
MOLLUSKS:			
NONE			
PLANTS:			
NONE			

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service.

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES IN MASSACHUSETTS

ommon Name	Scientific Name	Status	Distribution
ISHES:			
Sturgeon, shortnose*	*Acipenser brevirostrum*	E	Connecticut River and Atlantic Coastal waters
EPTILES:			
Turtle, green*	*Chelonia mydas*	T	Oceanic straggler in Southern New England
Turtle, hawksbill*	*Eretmochelys imbricata*	E	Oceanic straggler in Southern New England
Turtle, leatherback*	*Dermochelys coriacea*	E	Oceanic summer resident
Turtle, loggerhead*	*Caretta caretta*	T	Oceanic summer resident
Turtle, Atlantic ridley*	*Lepidochelys kempii*	E	Oceanic summer resident
Turtle, Plymouth red-bellied	*Chrysemys rubriventris bangsi*	E	Plymouth County - possibly Naushon Island, Dukes County - Critical Habitat in Plymouth County, approximately 3,269 acres south of town of Plymouth
IRDS:			
Eagle, bald	*Haliaeetus leucocephalus*	E	Entire state
Falcon, American peregrine	*Falco peregrinus anatum*	E	Entire state - re-establishment to former breeding range in progress
Falcon, Arctic peregrine	*Falco peregrinus tundrius*	E	Entire state migratory - no nesting
MMALS:			
Cougar, eastern	*Felis concolor cougar*	E	Entire state - may be extinct
Whale, blue*	*Balaenoptera musculus*	E	Oceanic
Whale, finback*	*Balaenoptera physalus*	E	Oceanic
Whale, humpback*	*Megaptera novaeangliae*	E	Oceanic
Whale, right*	*Eubalaena* spp. (all species)	E	Oceanic
Whale, sei*	*Balaenoptera borealis*	E	Oceanic
Whale, sperm*	*Physeter catodon*	E	Oceanic
LLUSKS:			
NONE			
ANTS:			
NONE			

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service.

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES IN CONNECTICUT

Common Name	Scientific Name	Status	Distribution
FISHES:			
Sturgeon, shortnose*	Acipenser brevirostrum	E	Connecticut River and Atlantic Coastal Wat
REPTILES:			
Turtle, green*	Chelonia mydas	T	Oceanic straggler in Southern New England
Turtle, hawksbill*	Eretmochelys imbricata	E	Oceanic straggler in Southern New England
Turtle, leatherback*	Dermochelys coriacea	E	Oceanic summer residen
Turtle, loggerhead*	Caretta caretta	T	Oceanic summer residen
Turtle, Atlantic ridley*	Lepidochelys kempii	E	Oceanic summer residen
BIRDS:			
Eagle, bald	Haliaeetus leucocephalus	E	Entire state
Falcon, American	Falco peregrinus anatum	E	Entire state - re-establishment to former breeding range in progress
Falcon, Arctic peregrine	Falco peregrinus tundrius	E	Entire state migratory no nesting
MAMMALS:			
Cougar, eastern	Felis concolor cougar	E	Entire state - may be extinct
Whale, blue*	Balaenoptera musculus	E	Oceanic
Whale, finback*	Balaenoptera physalus	E	Oceanic
Whale, humpback*	Megaptera novaeangliae	E	Oceanic
Whale, right*	Eubalaena spp. (all species)	E	Oceanic
Whale, sei*	Balaenoptera borealis	E	Oceanic
Whale, sperm*	Physeter catodon	E	Oceanic
MOLLUSKS:			
NONE			
PLANTS:			
NONE			

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service.

NEW HAMPSHIRE FISH AND GAME DEPARTMENT
34 BRIDGE STREET
CONCORD, N.H.

CHAPTER Fis 1000 CONSERVATION OF ENDANGERED SPECIES

Statutory Authority: RSA 212-A

PART Fis 1001 PROTECTED SPECIES

Fis 1001.01 Endangered. Under the authority of RSA 212-A:6, IV (a), the following species, listed by common and (scientific names, shall be considered endangered.

	Common Name	Scientific Name
(a)	Sunapee Trout	(*Salvelinus aureolus*)
(b)	Short-nosed Sturgeon	(*Acipenser breviostrum*)
(c)	Bald Eagle	(*Haliaeetus leucocephalus*)
(d)	Peregrine Falcon	(*Falco peregrinus*)
(e)	Lynx	(*Lynx canadensis*)
(f)	Indiana Bat	(*Myotis sodalis*)

Fis 1001.02 Threatened. Under the authority of RSA 212-A:6 IV (a), the following species, listed by common and (scientific) names, shall be considered threatened

	Common Name	Scientific Name
(a)	Common Loon	(*Gavia immer*)
(b)	Cooper's Hawk	(*Accipiter cooperii*)
(c)	Marsh Hawk	(*Circus cyaneus hudsonius*)
(d)	Red-shouldered Hawk	(*Buteo lineatus*)
(e)	Osprey	(*Pandion haliaetus carolinensis*)
(f)	Upland Sandpiper (Plover)	(*Bartramia longicauda*)
(g)	Common Tern	(*Sterna hirundo hirundo*)
(h)	Arctic Tern	(*Sterna paradisaea*)
(i)	Roseate Tern	(*Sterna dougallii dougallii*)
(j)	Whip-poor-will	(*Caprimulgus vociferus*)
(k)	Purple Martin	(*Progne subis subis*)
(l)	Eastern Bluebird	(*Sialia sialis*)
(m)	Pine Marten	(*Martes americana*)

Fis 1001.03 Accidental Taking. Any species listed in Fis 1001.01 or Fis 1001.0 which are accidentally taken shall be immediately turned over to the nearest conservation officer.

PART Fis 1002 PROGRAMS ESTABLISHED

Statutory Authority RSA 212-A:9, I

Fis 1002.1 Programs. There shall be, at a minimum, the following programs established: Public awareness, information and education; law enforcement, protection; status and inventory studies of raptors and shorebirds; restoration of Sunapee Trout; furbearer census; and Common Loon management.

TECHNICAL MEMORANDUM
SOCIOECONOMIC IMPACTS

Prepared by
Wallace, Floyd, Ellenzweig, Moore, Inc.
Cambridge, Massachusetts

SOCIOECONOMIC

Introduction

Socioeconomic analysis is being considered in two parts at this stage of the project: The first deals with an overall compilation of data and literature review which profiles the characteristics of the social and economic environment of the state; while the second addresses the specific socioeconomic impacts associated with each of the supply alternatives to be analyzed during Phase 2. It is the latter effort which will be the principal focus for consideration of socioeconomic impacts which remain a more site-specific element of this analysis.

For this first part of the work, the general categories of information under socioeconomics have been examined and reported within the reveiw of the Demand/Use, conservation, and Land Use topices. This is because all of these topics incorporate socioeconomic concerns at the present broad level analysis. Such data includes population and demographic characteristics, housing characteristics, employment and income, and taxes. Industrial uses and other land use patterns, availability of public utility services, and the constraints on growth and development are also incorporated within those topics. This particular data will be examined in greater detail to determine the specific socioeconomic impacts within the analysis of impacts for each alternative. It was deemed sufficient at this stage of the project to rely on the coverage encompassed by the effort in the other tasks.

For the second part of the work, encompassing assessment of the specific socioeconomic impacts, there are five principal issues to be addressed for which data and information are being reviewed:

1. Socioeconomic impacts associated with implementation or construction/operation of the supply alternatives, including

   - local employment, labor force, and population data in communities likely to be affected,

   - previous socioeconomic impact studies of similar projects and the impact factors and multipliers employed;

2. The degree to which inadequate water supplies could constrict growth and economic development in communities currently or potentially served by MDC, looking at

   - industrial, commercial, and residential water use, permit activity and projected needs,

- effect of permit restrictions or water allocations on development based on case studies done in other regions (Boulder, Monterey, etc.);

3. The effect of water pricing changes due to demand management strategies or costs associated with development of new supplies

   - water costs as a component of commercial, industrial, and residential operating costs in different situations,

   - previous studies of price impacts for either sewer service or water charges to determine the effects of water pricing by income levels on individual users and groups;

4. The effect of water use restrictions associated with conservation strategies such as watering bans

   - previous studies (e.g., California, suburban Washington, D.C., Denver); and,

5. Socioeconomic impacts of the alternatives on economic development prospects in downstream communities and in receiver communities

   - projected economic growth and benefits from available water supplies,

   - projected adequacy of water supplies,

   - potential adverse impacts of reduced supplies.

Questions that Need to be Addressed

These five issues provide a basis for the overall socioeconomics task and will be analyzed in greater detail under the assessment of impacts of various supply alternatives, during Phase 2 of the project. The review and evaluation of the data carried out during Phase I in conjunction with the Demand/Use and Conservation tasks has served as preparation for this upcoming analysis.

Data Review and Evaluation

The data dealing with broad social and economic characteristics, as noted above, is found in the Demand/Use, Land Use, and Conservation memos. For most data categories, socioeconomic data pertaining to statistics on employment, housing, income, etc., is available and generally complete. Some information is dated and updates will be necessary. The 1980 Census and associated reports will provide some of this update.

For issues that involve data based on work in another task, such as employment impacts that use statistics compiled under commercial and industrial usage profiles, the data update will utilize work already carried out. The data dealing with specific alternatives cannot be reviewed in detail until the alternatives are more fully defined and impact assessment begins. However, the literature review indicates that data on current and projected water supplies of potentially impacted communities are dated and inconsistent, and that community specific or industry specific impacts may be difficult to estimate without additional data and updating. It is anticipated that additional information will be available from the local user and industrial surveys to be carried out in the next stage of the analysis, but some gaps at the local level pertaining to site-specific impacts may still remain. Where there are gaps, further surveys may be required.

Method of Analysis

Since the detailed socioeconomic analysis is site specific, work under this task so far has been to organize and cordinate all of the related data that exist among the related topics identified above in order to prepare for subsequent work in Phase 2. Work to be done in this stage of the analysis includes validation of key data sources and analysis using information such as existing studies and impact reports, available (though sometimes outdated) statistics and data, contacts and interviews with regional and local planning officials to identify significant growth trends and new major developments, identification of anticipated future trends and likely impact categories for later analysis, and review of the relationship of these issues to the questions being analyzed in the other related impact topics.

Much of this work will continue to overlap with work in the other tasks identified and will, therefore, be coordinated with those tasks throughout until the impact analysis. The analysis, at this stage also, is being designed to take advantage of the upcoming 1980 census reports as they become available, particularly in the areas of income, employment and housing.

The bibliography encompassing socioeconomic concerns is incorporated by the listings for the Demand/Use, Conservation and Land Use topics and is not, therefore, repeated in this memo. A separate bibliography identifying particular socioeconomic references will be included in the reports discussing subsequent impact analysis.

NCAC Comments: Socioeconomics

1) Q: Page 1 - #1 - There should be some elaboration as to which "previous similar projects" will be compared to the supply alternatives under investigation in the present study.

A: The types of projects to be analyzed for comparison of similar impact factors and multipliers is intended to identify the magnitude of those impacts as reported by those studies. It is not anticipated that such comparison will focus on any one particular study, but rather several that have been done in recent years. The kinds of studies to be analyzed for possible comparison include those done for the Washington Suburban Sanitary Commission (October 1977, and 1979).

2) Q: Page 1 - #2 - When the section on effect of inadequate water supplies on growth and economic development is developed, other factors such as availability and cost of energy, tax structure, and general economic health should also be considered. Will this be a regionwide survey of potential growth and economic development?

A: The analysis of the effects of inadequate water supplies on growth and economic development will be a regional assessment. The types of data to be analyzed will be determined after discussing the information available at the RPA's and assessing their outlook on growth and development within the region. It is anticipated that those factors identified above as well as others reviewed in the literature search will be analyzed.

3) Q: Page 2 - #5 - The phrase "flood skimming" should be defined. Analysis of projected water usage should include: agriculture, power generation, recreation, fisheries restoration, etc.

A: Flood skimming is defined under the discussion of the Engineering Alternatives. Under the assessment of socioeconomic impacts, the downstream usage of water will address major land uses and will focus on the employment and income elements of that usage.

4) Q: Page 2 - Under "Data review and evaluation" - It would be helpful for the reader to know exactly which "other technical memoranda" are referred to, as well as page numbers for such cross-references. How will the 1980 census figures be incorporated into this memo.

A: The reference to other technical memoranda relate specifically to the Demand/Use memo, with some added information also to be found in the Land Use memo. Because socioeconomic issues at this point are of a broad nature, such as those dealing with issues of growth and development at local and regional levels, and encompass a variety of issues that overlap with those addressed i[n] the other memos no further detail was provided here. Rather the information outlined in the memo focuses on those questions that pertain to socioeconomic impacts as they relate to Demand/Use and Land Use considerations in this sta[ge] of the analysis. The subsequent analysis for the EIR will look at the specific impacts of each alternative and the socioeconomic factors that are separate from those analyzed in other memos.

1980 census data on housing characteristics, income levels, and demographic breakdowns will be a part of the baseline information from which the

socioeconomic impact assessments will be developed. It should be pointed out that there will remain much overlap between analysis under this topic and the Demand/Use and Land Use topics so that coordination will continue throughout the analysis.

5) Q: Page 3 - top paragraph - What kind of "additional data and updating" are needed in order to estimate "community specific or industry specific impacts"?

A: The proposed survey of industry and interviews with local water departments are intended to provide specific information on a variety of use characteristics and help us to develop user profiles. This information will catalogue the actual use and supply trends of communities and specific industry to enable better updates and projections to be made than from published data alone.

5) Q: Page 3 - last paragraph - It would be helpful to know exactly where all references are listed; it would also be helpful to have all references cited throughout the body of the memo by author's last name and date of publication.

A: See revisions in text.

LAND USE
TECHNICAL MEMORANDUM

prepared by

WALLACE, FLOYD, ELLENZWEIG, MOORE, INC.

LAND USE

INTRODUCTION

The literature search for the Land Use task in Phase I has focused on data which addresses broad scale issues of land development, growth trends, and factors which influence the pattern and make-up of land uses. Existing land use information at state, regional and local levels was reviewed under this task and in conjunction with the Demand/Use and Demand Management tasks as they pertain to types and patterns of development. The broad scale focus is intended to provide an overview to land use issues that pertain statewide and would encompass all the present alternatives; site specific impacts to be addressed under each alternative will be analyzed during Phase 2.

Among the statewide issues considered, particular attention was paid to existing plans and policy statements at regional and local levels which consider future directions of growth and development, constraints that may exist to growth and development, and any specific influences that result from either the availability or unavailability of water and related utility services. This latter question also involved looking at existing so-called growth moratoria which may limit development in a particular area.

Another key issue is the protection of aquifers and recharge zones through land use controls at both local and regional levels.

Some of the sources of information on land use include maps and aerial photos of the state's land areas, descriptive classifications of land use by categories, data from plans and studies conducted by state agencies including the Coastal Zone Managment program and NERBC, and local and regional planning studies.

The literature search identified sources of current data in this topic which were later analyzed. The discussion below summarizes the results of this analysis and presents our plans for continued work on this topic.

QUESTIONS TO BE ADDRESSED

The issues addressed in the land use topic will examine the relationship of local land use and development patterns with water supply. Included in these are:

- The effects of land use upon the availability and quality of water;
- The availability of water as an influence upon future development;
- Development controls and restrictions related to water supply and availability locally;
- Land use trends and growth policy on a regional level; and,

- Land use trends and growth policy on a regional level; and,

- Natural resource elements of land use including issues relating to protection of wetlands, aquifer recharge areas, recreational resources, and others.

These questions will be addressed broadly as the alternatives are being developed, and in greater detail once the specific impacts of each alternative are analyzed.

DATA REVIEW AND EVALUATION

Existing Land Use Plans

The data on land use is current and sufficient for a baseline analysis of the issues in all affected areas pertaining to land development trends and patterns of land use, although detail and breadth vary by region. Most regional planning agencies (RPAs) have current data on land use in their re- gions, either in the form of land use maps, sections of a published "208" water quality report, or comprehensive land use studies. The type and quality of the data varies from region to region, but generally includes mapping of natural resources, housing density, public utilities, and land use patterns by development categories on both regional and municipal scales; land use studies which address regional and local growth issues, such as impacts of development; quantified data on development characteristics; and studies on land use as it affects water quality. Individual re- gional issues such as amendments to the zoning code or recreational plans are also discussed.

At the local level data is generally available on zoning and land use for each municipality; however, the accuracy and coverage of this data as well as its currency and consistency varies a great deal. Most data directly applicable to the study will be found at the regional level.

The Metropolitan Area Planning Council (MAPC) is the largest of the RPA's within the study area and their library is a good source for references on a variety of land use and related issues for its 101 member communities. Although not comprehensive, the publications address such topics as the hydrology of Great Meadows and growth patterns in Massachusetts. Other regional agencies can provide information on land use and development patterns and trends.

Growth Moratoria/Policies

Due to the widespread application of moritoria and similar restrictions on land use/development across the Commonwealth, this issue has been addressed in the literature review. A growth moratorium refers to a local

regulation or policy which seeks to limit or prohibit development in an area.

Typically these development controls are based upon unavailability of public services, usually water or sewer service, to new customers. In some cases a town will limit a certain type of development, such as multi-family residences or industrial users, for either a specified short term or a longer period of time. All moritoria that have been identified at this stage of the study are utility or public services related.

Written information on all moratoria is available on file at the Massachusetts Attorney General's Office. There is a town by town file with current legal information on growth moratoria and zoning amendments. However, there is no cross reference listing of towns with growth moratoria or recent zoning amendments. For the purposes of this study, therefore, we will first identify the study area communities before addressing this question in greater detail.

The definition of a growth moratorium varies greatly by municipality and includes a wide range of measures designed to affect or inhibit growth according to each locality's particular planning responses to existing or anticipated problems.

Few comprehensive references are available on growth moratoria; most of the information was gathered by contacting the nine regional planning agencies whose areas encompass the alternatives. The data obtained at this stage is still general since overall trends and policy was being researched. It was learned from these interviews that the RPA's do not have a current, comprehensive listing of towns with moratoria. Rather the information was culled from local sources including calls to local planning boards. It was determined that contacting individual towns to determine the status of their moratoria was the only reliable source for data. This was done for a sample of towns in order to determine the degree to which this restriction technique was being employed and how it was used. One town, for example, has recently enacted a one year moratorium on industrial development; another has a 10-year ban on high-density apartment complexes. Exhibit 1 lists the controls that have been locally enacted in the Merrimack Valley Regional Planning Commission.

Staff of the Massachusetts Executive Office of Communities and Development and of the Home Builders' Association of Massachusetts were also contacted for land use information on cities and towns, but their data proved to be of a general nature only.

In the literature review, four of the nine regional planning commissions contacted -- Franklin County Planning Department, Lower Pioneer Valley Regional Planning Commission, Old Colony Planning Council and Merrimack Valley Planning Commission -- have a regional growth polic or plan. A variety of issues are addressed by these studies ranging from controlled growth plans to limits on certain development types. For example, a Franklin County study includes population projections and estimates of the amount of land which has been and will be developed for various future land uses. Individual towns, such as Plymouth, also have growth policies that reflect the availability of local utility services and associated impacts.

The Growth Policy Commission, established by the state legislature in 1973, is a valuable source of information c current legislation and policy issues relative to local, regional and statewide growth trends and problems. For example, Charles Perry, Research Director of the Commission, cited the Chilmark case which involves legislation enabling that community to regulate the number of units built each year. Further data will be gathered through interviews with state and regional officials, as well as at the local level in order to further define the use and effectiveness of this technique as a growth management tool in the state.

Figure 2 lists the data examined and available from the sources contacted. This list will be further reviewed during the Additonal Services phase to identify more specific growth and development trends with particular attention to any possible water-related impacts upon land uses within each of the identified study area communities.

Method of Analysis

Further definition will be made of the critical land use issues as perceived at the regional and local levels. The data and sources covered in the literature review have shown that the broad question of land use is a variable or that affects local municipalities differently and is addressed in varying ways by cities and towns. The genera issues to be analyzed will define the parameters of existing land use and development controls and policy at the local level, regional and/or statewide growth issues, and the elements which contribute to land use patterns and effect a region's development, including the availability of water as a resource for economic growth.

More detailed analysis of the associated land use impacts under each supply alternative will be addressed based upon the broad analysis described above, during Phase 2 of the project.

Fig. 1

Towns With Growth Moratorium

Merrimack Valley Planning Commission

1. No multi-family allowed:	Amesbury Boxford Groveland Newbury Salisbury West Newbury
2. Multi-family by special permit only:	Haverhill Rowley
3. Multi-family allowed in special districts by special permit:	Andover Newburyport Georgetown
4. Apartment moratorium:	North Andover
5. Multi-family moratorium three years (1977-1980):	Rowley

Fig. 2

Matrix of Land Use Data by RPA and Other Sources

	Resource Maps	Land Use Maps	Quantified Land Use Data	Land Use Plan	Land Use/ Water Quality Study	Growth Policy/ Study	Growth Plan	Growth Moratoria	Land Use Policy
Montachusett Planning Commission				X - Limited Info in "Water Quality", also Montachusett-Nashua	X - Limited Info in "Water Quality Management Plan			X	
Northern Middlesex Planning Commission		X	X	X				X	
Old Colony Planning Commission					X		X	X	
Southeastern Regional Planning and Economic Development District				X - Limited Info in 208 Report					X
Massachusetts Attorney General's Office								X	
Communities and Development								X	
Home Builders Association of Massachusetts								X	
Growth Policy Commission						X	X		

Fig. 2 cont'd

Matrix of Land Use Data by RPA and Other Sources

	Resource Maps	Land Use Maps	Quanti-fied Land Use Data	Land Use Plan	Land Use/ Water Quality Study	Growth Policy/ Study	Growth Plan	Growth Moratoria	Land Use Policy
Central Massachusetts Regional Planning Commission		X	X					X	
Franklin County Planning Department		X	X	X		X		X	
Lower Pioneer Valley Regional Planning Commission		X		X - Limited info in 208 study		X	X	X	
Merrimack Valley Planning Commission					X	X	X	X	
Metropolitan Area Planning Council	X	X		X - Limited Info. in Charles River Study also	X - Waste Treatment	X		X	X
Statewide data & maps (i.e., aerial photos, land use maps, natural re-source maps)	X	X	X						

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1978. Revitalizing Clinton's Downtown Business District.

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Northern Middlesex Area Commission. 1978. Land-Use and Water Quality. Lowell, Massachusetts.

Old Colony Planning Council. 1976. Growth Policy Statement. Brockton, Massachusetts.

____________________. 1976. Land-Use/Water Quality Issues in the Old Colony 208 Area. Brockton, Massachusetts.

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Peskin, Sarah. 1978. Guiding Growth and Change. Boston, Massachusetts: Appalachian Mountain Club.

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LAND USE: Response to Comments:

1. Q: There should be a more elaborate statement in the introduction relating protection of aquifers and recharge zones by land use controls and its impact on providing needed open space for aesthetic and recreational purposes, as well as water supply protection. Examples of failure to do this are many and the result of some of these are in the literature (e.g., Coffin and Richardson, 1980, examples in Data Matrix). (NCAC 6/15/80)

   A: Although it is not within the scope of the present study to address the relationship of land use controls and their impact on open space, an important consideration is their impact on water supply protection. Relative to land use controls and regulations which protect or influence groundwater resources and aquifers, most activity occurs on a local level. There are no state or federal regulations, with the exception of a statute which forbids the siting of a hazardous waste facility on an aquifer, which deal directly with the issue of aquifer protection.

   Phase II will involve a closer analysis of this issue, both as a general issue of concern, and as it pertains to the alignments of the relevant alternatives.

2. Q: Existing Land Use Plans - other RPAs (besides MAPC) should be good sources of information on land use and related issues for their respective communities. For instance, the Lower Pioneer Valley Regional Planning Commission has data for 43 towns. (NCAC 6/15/80)

   A: As mentioned in the technical memo, the other RPAs are valuable sources of information on a variety of land use issues. All the RPAs in the study area have been contacted for any information and data pertaining to this task. The information on a town-by-town basis is, however, not always current, as is the case with LPVRPC. Contacts there suggest contacting individual towns for the most current information.

3. Q: Method of Analysis - page 4 - what does the first paragraph mean, and what precise methodology will consultants use? (NCAC 6/15/80)

   A: As explained in the aforementioned paragraph, the analysis of a variety of land use issues will continue in Additional Services and Phase II. At present it is not possible to determine a precise methodology for the Phase II analysis as the type and depth of land use data needed will vary according to the alignments of the alternatives.

4. Q: Was the NERBC computer used?

   A: No, they no longer have a computer; it has not been in their office for a few months.

5. Q: Is the agricultural component included in the land use analysis?

   A: This is included in the general land use analysis, particularly in those cases where extensive irrigation is involved.

6. Q: Is zoning being addressed in the land use element? (6/6/80 meeting)

   A: Zoning is included as one method of land use control. However, it is not the only method, and often not an accurate prediction of growth, particularly in cases of non-conformance.

TECHNICAL MEMORANDUM
SIGNIFICANT CULTURAL RESOURCES

Prepared by
Wallace, Floyd, Ellenzweig, Moore, Inc.
Cambridge, Massachusetts

SIGNIFICANT CULTURAL RESOURCES

SUMMARY

Data on significant historic, archaeological, geological, scenic and cultural resources is adequate. The impacts of the alternatives on these resources will be evaluated when their alignments are defined.

INTRODUCTION

The term significant resources encompasses a broad range of natural and/or man-made features deemed irreplaceable by local, regional, state or federal government. It includes historic sites on or eligible for the National Register of Historic Places; archaeological sites of local, state or national significance; publicly owned parks or recreation areas; and geological features declared significant by the state geologist.

These resources are protected by various interest groups and state or federal laws because their loss would detract from the quality of the surrounding environment.

The physical facilities of the alternatives might directly or indirectly impact the significant resources either during construction or as a result of operation. Consequently it is necessary to include consideration of the potential effects in the planning process.

LITERATURE SEARCH

A literature search has been conducted for data on significant historical, archaeological, geological, scenic and cultural features within the study area included from the Connecticut River Valley to the eastern Massachusetts coastline.

Historic and Scenic Resources

In the literature search numerous contacts were made at the state and local levels to include coverage across the state (see bibliography and source list of contacts). The data is relatively adequate and current for an analysis of potential impacts on significant historic sites and scenic and cultural resources. The Massachusetts Historical Commission is an excellent and comprehensive source of information on historic sites and recent preservation activities in the state. The Commission also has a comprehensive listing of statewide local and regional historical societies, providing a solid network of resources and information. Most of the regional planning commissions have information on historic sites within their areas of responsibility; and local historic commissions can provide site specific information within particular localities.

Archaeology and Geology

Adequate data and resources are available for information on archaeological, paleontological and geological features both locally and statewide; however, more site specific research in these areas may have to be undertaken when detailed analysis of the alternatives begins. The State Archaeologist, Valerie Talmage, Massachusetts Historical Commission, will review the various alternatives to determine the extent of impacts on known archaeological sites. Sources at the University of Massachusetts at Amherst can provide information on archaeological activities in the Connecticut Valley area once the alternatives have been delineated. These two sources will provide the most complete and up to date information.

	Mass. Historical Commission	State Archaeologist	RPA's	D.O.I	USGS	Individuals Contacted
Historic						
Local Sign.	X		X			
Regional Sign.	X		X			
National Sign.	X			X		D. Gillespie Nat. Trust for Hist. Preserv.
On NRHP	X					F.McManamon,NP
Eligible NRHP	X					S. Cole, MHC
Current Preserv. Activities	X					
Archaeological						
Prehistoric	X	X				V. Talmage
Historic	X	X				Dina Dincauze
Current Activ.		X				
Geological						
State Geology					X	J. Sinnott, State Geologis
Regional Geology					X	J. Sinnott
Current Research					X	P. Barosh Mike Pease, US

	Mass. Historical Commission	State Archaeologist	RPA's	D.O.I.	USGC	Individuals Contacted
Scenic Helen Chapell, Tourism, Comm. of Massachusetts		X		X	X	
Cultural Susan Amory				X	X	

There appear to be no significant gaps in the information and the data base is adequate.

RECOMMENDED METHODOLOGY

At present there is adequate information to analyze the impacts of the alternatives once their facilities and alignments are described. Known sources at the regional and local levels will be contacted at that time to determine which if any resources are affected. Site specific testing will be done, if deemed necessary, for the alternatives being examined. Potentially impacted resources will be identified and described; potential impacts and measures to mitigate adverse impacts will be outlined.

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1963. Surficial Geology of the Concord Quadrangte. Boston, Massachusetts.

INDIVIDUAL CONTACTS

Ralph Abele Dept. of the Interior, Fish & Wildlife 1 Gateway Center Newton, MA 965-5100	RE information on geology. He has a number of publications for Eastern, MA
Dorothy Altman Merrimack Valley Planning Commission 87 Winter Street Haverill, MA 374-0519	RE information on historic sites. She has a listing of properties on the National Register, but it is not up to date
Susan Amory Council on the Arts & Humanities 1 Ashburton Place Boston, MA 727-3668	RE cultural sites in the state. Primarily a funding agency, not an information source, although they do provide basic tourist information on scenic/cultural sites in MA.
Dave Ashendon MDC Geologist Quabbin Reservoir 1-413-323-6921	RE information on geology
Patrick Barosh Weston Observatory Weston, MA 899-0950	RE information on geology.
David Beall Great Meadows National Wildlife Refuge Weir Hill Road Sudbury, MA 443-4661	RE information on geology. He is also involved with MDC in water resources planning.
Marlon Billings Professor of Geology Harvard University 495-2351	RE information on geology. He was suggested as a contact by Ralph Abele. He has numerous good source books on file. Also, he has worked with the MDC on the proposed tunnel from Quabbin reservoir.
Christy Boulding, Survey Director Massachusetts Historical Commission 294 Washington Street Boston, MA 727-8470	RE historical sites. She was the survey director for a survey of historical sites in MA. Information is on survey forms in their files.

Mrs. Burton Soil Conservation Service 153 Broadway Raynham, MA	RE soil surveys. Their office has maps for northern Bristol County and Plymouth County.
Leona Champeny South Great Road Lincoln, MA 259-9028	RE information on geology. The Sudbury River is her area of specialty; she is particularly interested in the Sudbury River alternative.
Helen Chapell Tourism Division Commonwealth of Massachusetts 100 Cambridge Street Boston, MA 727-3201	RE unique resources. Publishes a catalogue for tour guides and travel agents which lists attractions.
Stephen Cole Massachusetts Historical Commission 294 Washington Street Boston, MA 727-8470	RE historical sites
John Connery MAPC 44 School Street Boston, MA 523-2454	RE historic sites. MAPC has files on every community with public buildings eligible for National Register status.
Dina Dincauze Dept. of Archaeology University of Massachusetts Amherst, MA 1-413-545-2221	RE information on archaeology. Excellent contact RE specific information on current activities in the CT Valley floodplain; she was recommended by many people.
Bob Flynn Northern Middlesex Area Commission 144 Merrimack Street Lowell, MA 1-454-8021	RE information on historic sites in their area; he suggested two publications.
David Gillespie National Trust for Historic Preservation 100 Franklin Street Boston, MA 223-7754	RE historic sites. NTHP maintains files on sites in local communities.
Bill Grant Central Massachusetts Regional Planning Commission 71 Elm Street Worcester, MA 1-756-7717	RE historic sites. CMRPC has one study in published form.

Mrs. Robert Graves Northfield, MA 1-413-498-5012	RE historic sites. Her husband was suggested as a contact by Marge Sackett. Both Mr. and Mrs. Graves are involved in historic preservation activities in their town.
Professor George Lewis Dept. of Geography Boston University Boston, MA 353-2526	RE information on local geology. He was formerly a member of the NCAC. He has done considerable research on geology for the NCAC and is familiar with the resources.
Ms. Lowe Old Colony Planning Council 232 Main Street Brockton, MA 583-1833	RE historic sites in OCPC's region
Preston Maynard Lower Pioneer Valley Regional Planning Commission 26 Central Street W. Springfield, MA 1-413-739-5383	RE historic sites. LPVRPC has an active file on each community.
Frank McManamon National Park Service Dept. of the Interior 15 State Street Boston, MA 223-3778	RE archaeological and historic sites. NPS has information on certain sites, within the park system.
Les Mehrhoff University of Connecticut Storrs, CT 1-203-486-4320	RE information on geology/natural history. His office is a clearing house for biological/geological publications.
Fred Meuhl Franklin County Planning Department Courthouse Greenfield, MA 1-413-774-3167	RE historic sites. FCPD has published published a document with a general description of historic sites.
Mike Pease United States Geological Survey 150 Causeway Street Boston, MA 223-7202	RE information on Massachusetts.
John Peck Stone & Webster Engineering Corporation 245 Summer Street Boston, MA 973-5111	RE geology. He was involved in developing the plan for the proposed nuclear power plant in Montague.

Chris Percy 125 Commbs Road Easthampton, MA 1-413-584-0057	RE information on geology. He is President of the Connecticut River Watershed Council. His associate, Terry Blunt, suggested numerous other contacts.
Jim Perrish Berkshire County Regional Planning Commission 10 Fenn Street Pittsfield, MA 1-413-442-1521	RE historic sites in Berkshire County.
John Pretola Springfield Science Museum 236 State Street Springfield, MA 1-413-733-1194	RE archaeology. The museum has a significant archaeological collection from Connecticut Valley.
Sid Quarrier United States Geological Survey Hartford, CT 1-203-566-3540	RE geology in the Connecticut River Valley.
Professor Robinnson University of Massachusetts Amherst, MA 1-413-545-0111, #2593	RE geology.
Marge Sackett Northfield Citizens Advisory Committee Springfield, MA 1-413-788-6165	RE contacts for historical/ archaeological information.
Dianne Siergiej Montachusetts Planning Commission survey. 150 Main Street Fitchburg, MA 1-345-7376	RE information on historic sites. Most towns in the MPC region have done a
J. A. Sinnott, State Geologist Environmental Quality Engineering Department 100 Cambridge Street Boston, MA 727-4797	RE information on geology.
Southeastern Regional Planning and Economic Development District 7 Barnabas Road Marion, MA 748-2100	RE information on historic sites.

Mr. & Mrs. Byron Stone United States Geological Survey Arlington, VA 1-703-860-6503	RE information on geology of the Connecticut Valley.
Valerie Talmage, State Archaeologist Massachusetts Historical Commission 294 Washington Street Boston, MA 727-8470	RE archaeological sites/activities. MHC maintains files on each site.
Dr. Charlotte Thompson Newbury, MA 1-465-5808	RE archaeological sites/activities. She is an independent consultant.
Bob White Natural Resources Center, Department of Environmental Protection Hartford, CT 1-203-566-3540	RE natural resources directory for the Connecticut River Valley.
Nancy Whittemore Pioneer Valley Association Northampton, MA 1-413-586-0321	RE cultural/unique resources.
Mr. Worrell Old Sturbridge Village Sturbridge, MA	RE archaeology. He is the staff archaeologist at Sturbridge. He is familiar with current activity in the Northfield area.

SIGNIFICANT CULTURAL RESOURCES

-Response to Comments-

1. Q: Everything is unique, title of this memo, "Cultural and Unique Resources", should be revised. (NCAC Workshop Questions 6/6/80).

   A: This suggestion was adopted immediately, as is apparent from the changed title on this response. Cultural rsources will be referred to as "significant", rather than "unique".

2. Q: Has the consultant included "wetlands" in this category? (NCAC Workshop Questions 6/6/80).

   A: The impacts of the alternatives on wetlands are being addressed in various memos, and should be reviewed in more detail in Phase 2 when the alignments and modes of operation of the various alternatives are known.

   Wetlands that lie along rivers and other bodies of water, and those that lie along the tunnel right-of-way will be addressed in the ecology and engineering sections respectively. A portion of the land use memo will focus on regulations and laws governing the use and/or protection of wetland areas.

TECHNICAL MEMORANDUM:
PUBLIC PARTICIPATION

PHASE I BASIC SERVICES

Submitted to

METROPOLITAN DISTRICT COMMISSION

by

WALLACE, FLOYD, ELLENZWEIG, MOORE, INC.

PUBLIC PARTICIPATION DURING PHASE I

Public participation has been an integral part of the study process during Phase I. Citizen interest in the study content and process was great and resulted in a public participation effort beyond the level specified in the consultant scope of work.

Activities under this task involved continuous communications and interaction with Northfield Citizen's Advisory Committee (NCAC) by the consultant and MDC, public information meetings, review session of draft technical memoranda, development of the study newsletter, and responding to inquiries received through a WATS line in the consultant office.

Mailing List

Among the first tasks undertaken by Public Participation Staff was the compilation of a study mailing list. The mailing list was compiled from various other mailing lists (NCAC, Watershed Associations, Sudbury CAC, legislators and public officials). This list of over 1,000 names has been used for mailings including notices for public information meetings. It has been updated monthly with names of individuals who have telephoned or attended meetings, and/or been recommended by others.

Public Information Meetings

Public information meetings have served as a forum for discussion and information exchange among citizens, study consultants and MDC. During Phase I there have been two sets of public information meetings. Each meeting was held twice -- once in Eastern Massachusetts and once in the Connecticut River Valley.

Preparation for the meetings included identifying locations; mailing notices; preparing agenda, graphics and handouts; writing draft press releases; and conducting meeting dry runs. The content of each meeting reflected the progress of the study.

The first set of meetings was held in Springfield on 29 April 1980, and in Boston on 1 May 1980. These meetings served to introduce the purpose and scope of the study. Presentations were made on the MDC water system; the purpose and scope of study; the progress of the study to date; and the purpose and structure of the NCAC. The MDC Commissioner also attended the meeting in Springfield. In Boston, there were approximately twenty-five people present while in Springfield, approximately fifty people attended the meeting.

In preparation for the first meeting, WFEM wrote and printed a four-page study project description of Phase I. This study description was distributed at the first

meeting. The MDC and NCAC distributed several hundred additional copies to interested citizens and officials. MDC made a special mailing to Massachusetts Legislators containing the description and an invitation to attend the second meeting in June.

The second set of meetings was held in Newton on 16 June 1980, and Northampton on 19 June 1980. These meetings consisted of short presentations by each consultant firm on the Draft Technical Memoranda for Phase I. The following areas were presented and discussed:

1.	Demand Use	WFEM
2.	Demand Management	WFEM
3.	Safe Yield/Streamflow	ADL
4.	Engineering	BI
5.	Water Quality & Ecology: Reservoirs and Local Supplies	NER
6.	Water Quality & Ecology: Rivers, Coaslines, and Tunnel Rights-of-Way	NAI
7.	Socioeconomic	WFEM
8.	Land Use	WFEM
9	Significant Cultural Resources	WFEM

The presentations were followed by animated question and answer sessions. In Newton, thirty-five people attended and forty-five were present in Northampton.

NCAC

Another major aspect of public participation during Phase has been the continuous communication and information exchange with the NCAC. In many ways citizen participatio in the Northfield EIR predates the beginning of Phase I in March 1980. The Citizens Advisory Committee on the propos Northfield Diversion Project (NCAC) was created by a Memorandum of Understanding signed by the Secretary of Environmental Affairs, the Massachusetts Steering Committe on the Connecticut River and the MDC in 1978, to play "a full formal advisory role in the preparation and review" o the Northfield EIR. It is composed of thirty-five members representing Eastern Massachusetts (12), the Connecticut River Valley (19), and the State of Connecticut (4). The MDC provides funding for the position of Executive Directo in addition to benefits, expenses and a portion of overhea costs. The initial two-year contract is presently being re-negotiated and will continue for the duration of the

EIR. Throughout Phase I, the team of consultants has exchanged information with the NCAC in various ways. At monthly progress meetings, the MDC, NCAC and consultants have discussed the progress of the study in detail. Since March 1980, the Study Manager for WFEM has presented full progress reports and answered questions at each NCAC monthly meeting. WFEM staff have also participated in several NCAC Task Force meetings. WFEM and other members of the consultant team have reviewed study-related information at the NCAC's office in Springfield. The NCAC Executive Director has participated in meeting dry-runs.

NCAC Workshop

An all-day review workshop was held at the MDC on 6 June 1980. The purpose of the workshop was to review the preliminary findings of Phase I and provide an opportunity for NCAC members, MDC staff, and other individuals to pose questions to the consultants. The review workshop was jointly planned by the NCAC, MDC, and WFEM. Copies of the Draft Technical Memoranda were prepared and distributed on an accelerated schedule to NCAC members and MDC staff prior to the workshop. For the most part, discussion centered around the conclusions reached by consultants. Because the findings were not available in written form for review prior to the meeting, the engineering consultant made a detailed verbal presentation of the preliminary findings. The workshop proved to be an effective mechanism for detailed discussion of the technical aspects of the study, facilitating citizen input into the study findings.

Comments on Technical Memoranda

Following the review workshop of 6 June 1980 and the Public Information Meetings of June 16th and 19th, written comments were received by the MDC and WFEM from various individuals and the NCAC. The NCAC reviewed each Technical Memorandum and submitted written comments to the MDC. Comments have been incorporated and/or answered at the end of each Technical Memorandum.

WATS Line

Another aspect of public participation during Phase I was the use of a long distance toll-free telephone line by Massachusetts callers outside the Metropolitan area. Public participation staff answered inquiries from NCAC and other interested citizens, as well as newspaper and radio reporters. Inquiries were mostly requests to be placed on the mailing list, information regarding public information meetings, the progress of the study, or specific points for clarification of technical findings.

Newsletter

The study newsletter "Water News" will be published to coincide with MEPA review. The first issue will summarize

the contents of the Phase I Basic Services report entitled Findings of Literature Review and Recommendations for Further Study. The newsletter is intended to provide wide dissemination of study findings and related issues. It wi be mailed to persons on the mailing list with additional distribution copies available at MDC and NCAC's main offic

Other Documents

Copies of the Phase I Report and Technical Appendices will be available through MDC, NCAC, and a number of public libraries and regional planning offices.

Recommended Tasks

The Northfield Citizen's Advisory Committee should continu to be funded and play a full formal advisory role througho the duration of the EIR. In addition, public participatio activities should include an intensified outreach effort t identify and inform impacted municipalities, continued information exchange through public information meetings a the WATS line, a special meeting with Regional Planning Associations, publication of study newsletter, media relations and continued liaison with NCAC.